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ABSTRACT

This study investigated the extent, causes, and means of preventing agricultural tractor accidents. The report includes an estimate of annual tractor-related deaths, an identification of the primary causes of such accidents with consideration of the major hazards causing death or injury, and recommendations or means for preventing the occurrence of and reducing the severity of injuries resulting from tractor accidents. Because of recent private initiative in tractor safety, Federal safety standards are not considered necessary at this time. Alternative recommendations include: (1) The tractor industry should intensify efforts to promote and market equipment with proper safety equipment, (2) The insurance industry should consider the feasibility of incentives for farm operators to choose safety features, and (3) States should require driver's licenses for operating tractors on public roads and should develop adequate accident reporting systems which will contribute to hard data for further research. (Author/BH)

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Agricultural Tractor Safety on Public Roads and Farms

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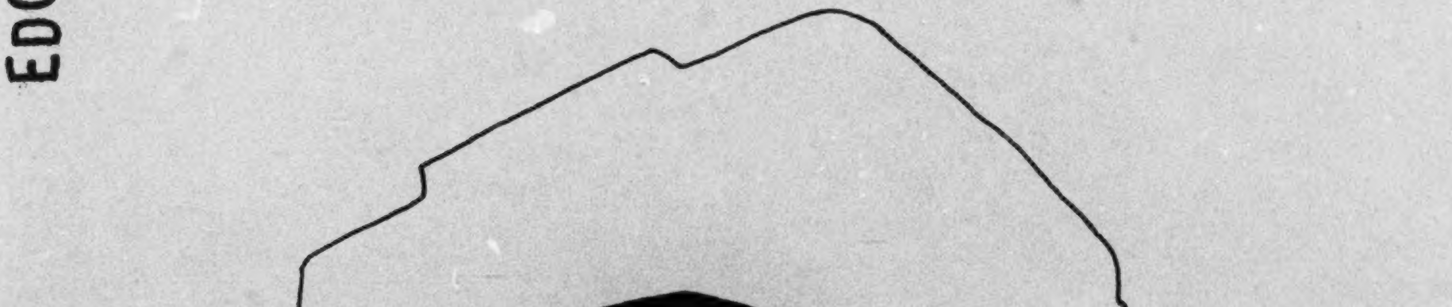

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A report to the
Congress
from the
Secretary of Transportation
January 1971

ED055229

THE SECRETARY OF TRANSPORTATION
WASHINGTON, D.C. 20590

December 31, 1970

Honorable Spiro T. Agnew
President of the Senate
Washington, D. C. 20510

Dear Mr. President:

I transmit herewith a report on the extent, causes and means of prevention of agricultural tractor accidents on both public roads and farms. This study is submitted in accordance with the requirements of section 8 of Public Law 91-265.

Sincerely,

John A Volpe

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THE SECRETARY OF TRANSPORTATION
WASHINGTON, D.C. 20590

December 31, 1970

Honorable John W. McCormack
Speaker of the House of Representatives
Washington, D. C. 20515

Dear Mr. Speaker:

I transmit herewith a report on the extent, causes and means of prevention of agricultural tractor accidents on both public roads and farms. This study is submitted in accordance with the requirements of section 8 of Public Law 91-265.

Sincerely,

John A Volpe

DEPARTMENT OF AGRICULTURE
OFFICE OF THE SECRETARY
WASHINGTON, D. C. 20250

December 16 1970

Honorable John A. Volpe
Secretary of Transportation
Washington, D.C. 20590

Dear Mr. Secretary:

We appreciate having the opportunity to examine and comment on the Department of Transportation report entitled Agricultural Tractor Accident Study prior to its submission to Congress. In our review we have given particular attention to the proposed Farm Machinery Safety Counter-Measure Program, and to the recommendation that the Department of Agriculture take the lead in providing overview and coordination of all Federal agency efforts to implement such a program.

It appears that certain of the specified recommendations could be carried out by expansion of existing Department of Agriculture programs. For example, our Statistical Reporting Service, which is currently employing an area-frame concept for collecting data on farm operations, could also be utilized to obtain reliable data, on agricultural tractor and farm equipment accidents. Our research staffs could analyze the data and conduct studies, especially those necessary to develop recommendations for safety standards. Extension personnel could intensify educational programs to reach the farm and agri-business community with information on avoidance of farm tractor and equipment accidents.

We in the Department of Agriculture recognize the need to reduce the hazards incident to agricultural activity. We will give the proposed safety program our full support within the limitations of available resources.

Sincerely,

N P Ralston

N. P. Ralston, Associate Director
Science and Education

AGRICULTURAL TRACTOR SAFETY
ON PUBLIC ROADS AND FARMS

A REPORT TO THE CONGRESS
FROM THE SECRETARY OF TRANSPORTATION

JANUARY 1971

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SUMMARY

Pursuant to the provisions of section 8 of Public Law 91-265, enacted May 22, 1970, a study was conducted on the extent, causes and means of preventing agricultural tractor accidents on public roads and farms. The report of that study includes an estimate of the number of deaths resulting annually from agricultural tractor accidents, an identification of the primary causes of such accidents with consideration of the hazards most likely to cause death or injury, and recommendations on means for preventing the occurrence of and reducing the severity of injuries resulting from tractor accidents.

The methodology of the study involved three major phases: 1) a detailed investigation and evaluation of the problem by a multidisciplinary task group, including a careful review of published articles and other material, field visits to major tractor manufacturing plants and to major test and farm operating facilities, and visits to universities where research is actively conducted on tractor safety problems; 2) solicitation of technical papers on a variety of selected safety topics from acknowledged authorities; and 3) scheduling of a public meeting to obtain a broad range of views and experiences from individuals and organizations concerned with agricultural tractor operations and accidents. Liberal use was made of existing sources of information, of the solicited papers and the proceedings of the public meeting in arriving at findings that are presented in the body of the report, and the papers and proceedings are included in full detail in the appendixes along with a reference list of publications.

DATA BASE

Based on available but fragmentary data, agricultural tractor accidents on public roads and farms claim the lives of 800 to 1,000 persons each year. Two-thirds to three-quarters of these occur on farms with the balance on public roads. About two-thirds of the fatal accidents are associated with tractor overturns, with side overturns predominating over rear overturns by a factor of three to one.

Data do not exist to estimate the number of tractor accidents each year or even to assess serious injuries resulting from such accidents. The hazards involved in accidents are found to be multiple, and represent factors involving the machine, operator, and environment.

Age of the tractor population is found to be critical to the imposition of safety standards in the design of new tractors and in retrofitting tractors in use. New tractors sold each year represent only about 3. 3 percent of the total population of 5 million tractors. The average age of agricultural tractors in use is 14. 3 years.

TRACTOR ELEMENTS

There is no single characteristic involved in tractor safety. Understanding is required of tractor stability and design features, and of tractor operations within an environmental complex. Design features affecting stability and tractor overturns, for example, include the location of wheels, spacing of the rear axle, dual wheels, suspension, power train, brakes, steering, wheelbase and hitchpoint. The high center of gravity, which also has a major affect on stability, has not changed appreciably over the years because tractors require high ground clearance for crop tillage operations.

Health hazards to the operator such as noise, vibration, dust and toxic fumes, and exposure to the elements, are adverse, subtle effects associated with sustained operation of a tractor.

Research aimed to improving the safety of the tractor is conducted at a number of universities or colleges, by individual tractor manufacturers, and by Federal agencies such as USDA and HEW. Working committees of the American Society of Agricultural Engineers (ASAE) and the American Society of Automotive Engineers (SAE) develop and issue safety standards for farm tractors; tractor manufacturers conduct tests of cabs or canopies as overturn protective devices to be fitted to their tractors in accordance with the ASAE-SAE standards. University personnel have undertaken continuous research in specialized areas such as power take-off accidents and overturn accident causation. One university under State law has tested tractors over a period of 50 years. USDA and HEW have been particularly concerned with health hazards and with operator training programs.

Current tractor models offer a number of safety features which represent the cumulative result of research and experience gained through years of field operation. Among the most notable improvements are the following:

o Overturn protective frames. The principal design countermeasure for ameliorating the effect of overturn accidents is the overturn protective cab or rollbar. ASAE-SAE standards for design and testing such devices have been developed and voluntarily accepted by the tractor industry. Three of six manufacturers visited during the study, however, still market cabs or canopies that are not overturn protective, hence can crush or trap the operator upon tractor overturn.

- Hydraulic self-equalizing brakes. To assist in making tight turns, tractor rear wheel brakes operate independently of each other. The practice of turning in one direction in field operations results in unequal wear of brake shoes. When brakes are locked together, such as is done while moving the tractor from one place to another, application of brakes tends to produce swerve which establishes potential for overturn. The hydraulic self-equalizing brake overcomes this problem.

- Power take-off shield. Power is transmitted from the tractor to associated machinery by means of a rapidly-revolving power take-off (PTO) shaft. Shielding devices in the past, being removable or providing inadequate coverage, have failed to give necessary protection. Shields currently being marketed are expected to reduce the possibility and seriousness of PTO accidents, and even more advanced shielding design is on the drawing boards.

- Independent PTO drive. Such mechanism permits the tractor operator to vary the speed of forward travel of the tractor while maintaining a constant PTO speed, consequently reducing the occasions when an attached machine becomes clogged. The operator now is able to vary the rate of travel (hence rate of machine feed) without simultaneously affecting the speed of the PTO.

- Tread width adjustment. Current models permit spacing the distance between the two rear wheels without having to unbolt the wheels, thus reducing the possibility of either the tractor or the wheel falling on the operator when adjusting tread width.

- Diesel fuel. Fire hazard is reduced, since almost all tractors produced today are diesel rather than gasoline powered.

- Fuel tank location. The fuel tank is located away from the engine today and therefore away from the source of fuel ignition.
- Stability. Wide front axle tractor types appear to have a more stable configuration. Approximately nine out of ten tractors manufactured today are of this type; ten years ago most tractors marketed were of the three-point or tricycle type.

OPERATOR ELEMENTS

Tractor fatalities affect operators that represent all age groups, including the under 15 and over 65 year groups. However, lack of data elements of agricultural tractor accidents preclude assessment of operator involvement as related to biographical factors, experience and skill requirements, education, and mental condition and physical handicaps.

Formal training programs are conducted in vocational agricultural programs and by the 4-H in its Tractor Care and Safety Program. Informal training programs include the publication and periodic reports on accidents by various colleges, the National Safety Council promotes a tractor overturn prevention and protection (TOPP) program, the Future Farmers of America chapters sponsor activities designed to promote farm and home safety, the Farm and Industrial Equipment Institute supports safety education programs and has promoted safety through the press, radio and television. Manufacturers encourage safe operation of their equipment through operator manuals, service manuals, and by providing decals bearing warnings and operating instructions on new machines. Also, one tractor manufacturer operates two dealer training farms and more than 12 thousand dealers and tractor customers have completed the course.

Formal training program development is lacking, however, for populations other than the 14- and 15-year old hired youths covered by the interim Hazardous Occupations in Agriculture Order issued in January 1968 by the Secretary of Labor. Training programs have yet to be developed for the purpose of maintaining the proficiency of the tractor operator or for developing the instructional skills of instructors of the training programs. Certain deficiencies in existing training programs also are noted.

Most States do not require a motor vehicle driver's license to operate a farm tractor on the highway.

ENVIRONMENTAL ELEMENTS

The multifunctional purpose of the tractor results in few environmental constraints in tractor use. Farming demands a seemingly all-purpose capability to operate over almost any kind of terrain in any type of weather, performing any power-related task. Yet little hard data is recorded on the status of environmental factors as they relate to accidents, injuries, and deaths.

Although the problem of tractor and associated farm machinery safety is primarily one related to various farm activities, tractors operating on public roads as slow moving vehicles along with high-speed motor vehicles is of concern because at least one-fourth of all tractor accident fatalities occur on public roads.

RECOMMENDATIONS

Uniform Federal safety standards are not recommended at this time. Principal reasons are:

- o Significant advances in the design of tractors to improve safety in operation have been made in recent years. There is evidence to suggest that continued progress by the tractor industry will provide improved safety systems and components.
- o Technical safety standards for tractor overturn, power take-off, and other safety hazard protection have been developed and updated by the American Society of Agricultural Engineers (ASAE) and the Society of Automotive Engineers (SAE). Manufacturers have voluntarily accepted the standards as design guides; for example, overturn protective cabs or rollbars currently are produced by all six manufacturers visited.
- o Overturn protective devices and other safety features increasingly are being recognized by farm operators as desirable; for example, about 20 percent of new tractors are being sold with protective cabs or canopies.
- o Engineering analysis suggests that current tractor models are safer than other models, and that accidents, injuries and deaths resulting from improper safety tractor design are more prevalent among older tractors.

As an alternative, recommended actions include the following:

- That the tractor industry increase its efforts to market tractors carrying safety equipment as standard rather than as optional equipment.
- That the tractor industry intensify its promotion of the continuous use of special safety features meeting safety standards.
- That the tractor industry take immediate steps to phase out the sale of products that do not meet ASAE-SAE safety standards such as cabs and canopies that are not overturn protective.
- That the insurance industry reassess its current practices in insuring farm operators against hazards, studying the feasibility of providing incentives for equipping tractors with safety features, meeting existing safety standards.
- That the lack of hard data to assess the full magnitude of the problem and to identify critical causes of death or severe injury be remedied by providing assistance to the States in developing an adequate accident reporting system.
- That States takes legislative action as necessary to require motor vehicle driver's licenses for operating tractors on public roads, and that tractors generally be required to comply with State rules of the road.
- That current procedures for Federal purchase of tractors be re-examined to rule out purchase of agricultural-type tractors not equipped with safety features providing maximum protection.

It is also recommended that the:

- U. S. Department of Agriculture be recognized as having prime responsibility for providing overview and coordination of Federal agency efforts in encouraging improved safety in tractor and other farm machinery operations.

- Congress authorize a follow-up study within five years of progress made through concerted, voluntary effort to prevent the occurrence of and reduce the severity of tractor accidents. At that time, if the engineering judgment indicated in the report as to the self-correcting nature of the problem proves not to be justified, uniform Federal safety standards should be required.

CHAPTER ONE

1.0 Introduction

This is a report on the extent, causes and means of prevention of agricultural tractor accidents on both public roads and farms in accordance with the requirements of Section 8 of Public Law 91-265, enacted May 22, 1970. The report includes, to the extent that such information is available, an estimate of the number of deaths and injuries resulting annually from agricultural tractor accidents, an identification of the primary causes of such accidents, with consideration of the hazards most likely to cause death or injury, and recommendations on means for preventing the occurrence of such accidents and reducing the severity of injuries resulting therefrom. As further required by Public Law 91-265, careful consideration has been given to the advisability of establishing uniform Federal safety standards in the design and manufacture of all agricultural tractors sold in interstate commerce, requiring the installation on such tractors of safety devices, and providing assistance to the States in developing accurate reporting procedures for accidents involving such tractors. For the purposes of this report, tractors are defined as agricultural wheel-type machines of 20 power takeoff (PTO) horsepower or greater, which are operated on or off the farm. Garden tractors, and industrial tractors both wheel- and track-type used in construction were not studied during the preparation of this report.

Several approaches were used in preparing this report. These include: (1) a careful review by a multidisciplinary task group within the National Highway Safety Bureau (NHSB) of published reports, studies, and other material available on tractor accidents, their causes or circumstances, and available countermeasures; (2) field visits to six tractor manufacturers and to tractor test and farm operating facilities; (3) visits or discussions with acknowledged authorities and researchers in universities, Federal departments or agencies, and non-governmental organizations, on specific elements of the problem of agricultural tractor safety; (4) invitations to researchers and other acknowledged experts to prepare and submit technical papers on a number of selected tractor safety topics; and (5) an extensively advertised public meeting (hereinafter referred to as "the Public Meeting") to obtain views and comments from the researcher, the farmer or farmer representative, the tractor manufacturer, the trade organization, and other concerned parties on agricultural tractor safety matters.

1.1 Organization of the Report

The report which follows is organized to take full advantage of the several methods of approach used in its preparation. Chapter 2 presents the magnitude of the agricultural tractor accident problem. Chapters 3, 4 and 5 discuss, in that order, the tractor, operator, and environmental aspects of the tractor accident problem to reflect the relative importance which has been attached to these elements in combatting deaths and injuries. Chapter 6 contains a discussion of current and proposed methods for reporting farm accidents, including those involving agricultural tractors. Chapter 7 contains the findings, conclusions, and recommendations.

In presenting the findings of the NHSB multidisciplinary task group, liberal use has been made of the technical papers prepared by specialists for this report, of the views and comments presented at or submitted in connection with the Public Meeting, of the discussions with various authorities including industry representatives, and of published material.

At the end of the report, preceding the Appendixes, is a list of 196 references (articles and other publications) used in the preparation of this report. In the Reference Section, entries are listed alphabetically by author and numbered accordingly. Throughout the report, the number which appears in parentheses after an author, a report, or a quotation, refers to a corresponding number in the Reference Section.

Appendix A contains the technical papers prepared at the invitation of NHSB for inclusion in this report. A total of sixteen papers on the following eight subject areas were invited:

- Agricultural tractor design
- Power takeoff units
- Tractor safety standards
- Accident reporting procedures
- Operator safety training
- Traffic laws and ordinances
- User acceptance of tractor safety devices
- Tractor crashes on public roads

Appendix B contains the proceedings of the Public Meeting, held for the purpose of obtaining views and comments on agricultural tractor safety from individuals and organizations concerned with these problems. This open meeting was held on September 17, 1970, in St. Louis, Missouri, a city which has proximity to a number of different agricultural regions utilizing tractors in farm operations. The proceedings include not only presentations at the Public Meeting, but also written communications received from concerned individuals who had views to express, but who were not able to attend the Public Meeting.

Appendix C is a table which shows the estimated tractor population for the years from 1940 through 1974 by tractor age groups.

Finally, acknowledgement is made of individuals from those Federal departments or agencies, manufacturers, trade associations, universities, and private organizations who cooperated by providing assistance to members of the NHSB multidisciplinary task group at various stages of the study. Among the Federal departments which provided input to the study were the U.S. Departments of Agriculture, Labor, Commerce, and Health, Education, and Welfare. The following manufacturers provided information to aid in the study: J. I. Case, Deere and Company, Ford, International Harvester, Massey-Ferguson, and White. Time did not permit visits to all tractor manufacturing facilities. Visits to these manufacturers were arranged through the Farm and Industrial Equipment Institute, which provided considerable additional information to aid the NHSB task group in its effort. Personnel from six different land-grant universities were visited and were most helpful during the course of the study: Purdue University, the University of Nebraska, the University of Iowa at Oakdale, the University of Minnesota, the Ohio State University and North Carolina State University. Again, time did not permit visits to all of the universities that have done creditable work in the field of agricultural tractor safety.

CHAPTER TWO

2.0 Magnitude of the Problem

In assessing the magnitude of the agricultural tractor safety problem, attention must be called at the outset to the limitations of available data on the number of accidents, injuries and deaths and the circumstances associated with such accidents.

There is almost universal agreement among data collectors and researchers, the tractor industry, and farmer representatives, that the lack of uniformity and broadbase coverage in collecting and reporting data precludes any attempt to develop more than approximate statistical parameters of the extent and nature of the problem. However, the absence of a concerted program to attack the tractor accident problem, and of homogeneous data that is representative of a well defined area of the farm community, has not deterred interested parties from pursuing independent investigations over the years. Reports of these studies have proved to be a primary resource for this study and report.

Some of the broad areas of limitations are as follows:

- The absence of any farm tractor registration requirement makes the present tractor count approximate at best.
- The frequency distribution of the tractor population by various functional characteristics which are pertinent to the safety problem is equally imprecise, when available.
- Much of the required data for deriving estimates appears only in reports which were published several years ago and which are now obsolete with respect to the current tractor population.
- No uniform reporting system exists for tractor accidents per se, nor are available State data summarized on a national basis, nor analyzed and reported annually as are other accident data.
- Fatal highway accidents involving farm equipment are required to be reported, but are seldom distinguished as to type of equipment or type of accident.

- Many functional or primary characteristics of the vehicle are not specified in accident reports.

- All States require that non-fatal highway accidents involving damages in excess of a specified amount be reported; but the reports involving farm tractors are not summarized separately.

A review of the research findings presently available shows the most reliable measure of farm tractor casualties to be fatalities. It is the opinion of the Bureau, however, that for the most part the discussions of causes and countermeasures which follow in this report will be applicable as well to accidents which produce non-fatal disabling injuries.

2.1 Total Number of Fatalities

An estimate of the total number of farm tractor fatalities, both on and off the highway, from 1957 through 1966 has been provided by the National Safety Council (NSC), and is shown in Figure 1. In 1966 the NSC made a detailed analysis of 789 deaths involving farm tractors in 13 States between 1960 and 1965 (105). The primary data sources were death certificates, summary data from death certificates, and newspaper clippings. Figure 1 shows that the 1960-66 estimate of farm tractor fatalities on both the farm and the highway is approximately 1000 per year. The NSC study indicates that this estimate is based on a tractor fatality rate of 22 deaths per 100,000 tractors. This rate may vary regionally due to differing types of tractors, usage and exposure.

Comparative data for independent studies in four different States are shown in Table 1, along with NSC data on the number of tractor involved highway fatalities, for the years 1965 through 1969. These four States are among the 13 providing input to the NSC study. It is apparent that the number of fatalities annually remains relatively stable. Data from these four States are all based on death certificates and supplemental accident reports which contain information on age and sex of victims, nature of injury, and time and place of the accident. Additional data on how the accident occurred is often obtained by inquiries directed to informants listed on the death certificate, from coroners, from attending physicians, and by reference to newspaper accounts of the accident. In some cases, investigations are conducted by insurance agents or by voluntary farm organizations. The data collection methods vary considerably in the States and in the research, and are tailored to fit the intended use of the individual States or researcher. Definitions of tractor, farm equipment, implement, farm, highway, overturn, falls, runover, and other data elements appear to be standard and compatible among these States. The data is, therefore, considered to be reliable and useful for counting or estimating the number of tractor fatalities.

Based on the above-limited sample of States, the NHSB has no reason to believe that the 1960-66 NSC estimate of approximately 1,000 fatalities, as indicated in Figure 1, has changed over the past five years. Hence, it may be expected that in 1970 the total number of fatalities will remain in the area of 1,000.

It should be pointed out, that the NHSB in its literature search has not found any pronouncement that the estimated 1,000 figure is increasing; however, two sources claim that the number of fatalities may already have reached its peak. The following statement is an excerpt from a paper prepared by W. E. Stuckey of the Ohio State University, one of the foremost experts in farm accident data collection and analysis:

> "Studies conducted at the Ohio State University indicate that we have had our 'ups and downs' in tractor fatalities per year since 1956. However, there has been a gradual reduction in fatalities while the number of tractors has remained about the same." (158:1).

L. W. Randt of the Farm and Industrial Equipment Institute (FIEI), had this to say at the Public Meeting with respect to the rate of accidents associated with farming:

> "The National Safety Council's 1966 edition of Accident Facts estimated that tractor accidents claimed the lives of about one thousand persons annually in the United States and that this represented a rate of 2.2 deaths per 10,000 tractors. More recent data from six States, Ohio, Minnesota, Wisconsin, Nebraska, Iowa, and Kansas indicate that the current fatality rate is lower, perhaps about 1.6 deaths per 10,000 tractors. A better estimate of the current rate may be about 800 fatalities per year." (Appendix B:B-48).

2.2 Farm Population

In order to present the 800 or 1000 fatality estimate in proper perspective, reference is made to Figure 2 which shows the farm population from 1950 through 1969. During this time-period the number of farmers dropped rapidly and in 1969 there were less than half as many farmers as there were in 1950. However, the 1969 population of 10 million farmers represents approximately 5 percent of the total U.S. population of 200 million.

2.3 Farm Tractor Population

Both the NSC and the FIEI have used tractor population as the basis of computing the rate of tractor fatalities. Figure 3 presents an estimate of the farm tractor population during the period of 1950 through 1969. This data, compiled by the U.S. Department of Agriculture(USDA),

TABLE 1 FATALITIES INVOLVING FARM TRACTORS BY LOCATION, 1965-1969

	1965	1966	1967	1968	1969	AVERAGE
KANSAS (65)						
FARM AND ROADWAY	22	25	22	26	22	23.4
NEBRASKA (136)						
FARM	33	29	25	23	23	26.6
ROADWAY	11	10	10	6	11	9.6
NORTH CAROLINA (126)						
FARM	30	38	44	35	35	36.4
ROADWAY	12	22	13	5	8	12.
OHIO (158)						
FARM	26	31	22	23	24	25.2
ROADWAY	9	10	12	11	10	10.4
NATIONAL SAFETY COUNCIL (107)						
ROADWAY	200	230	270	210	230	228

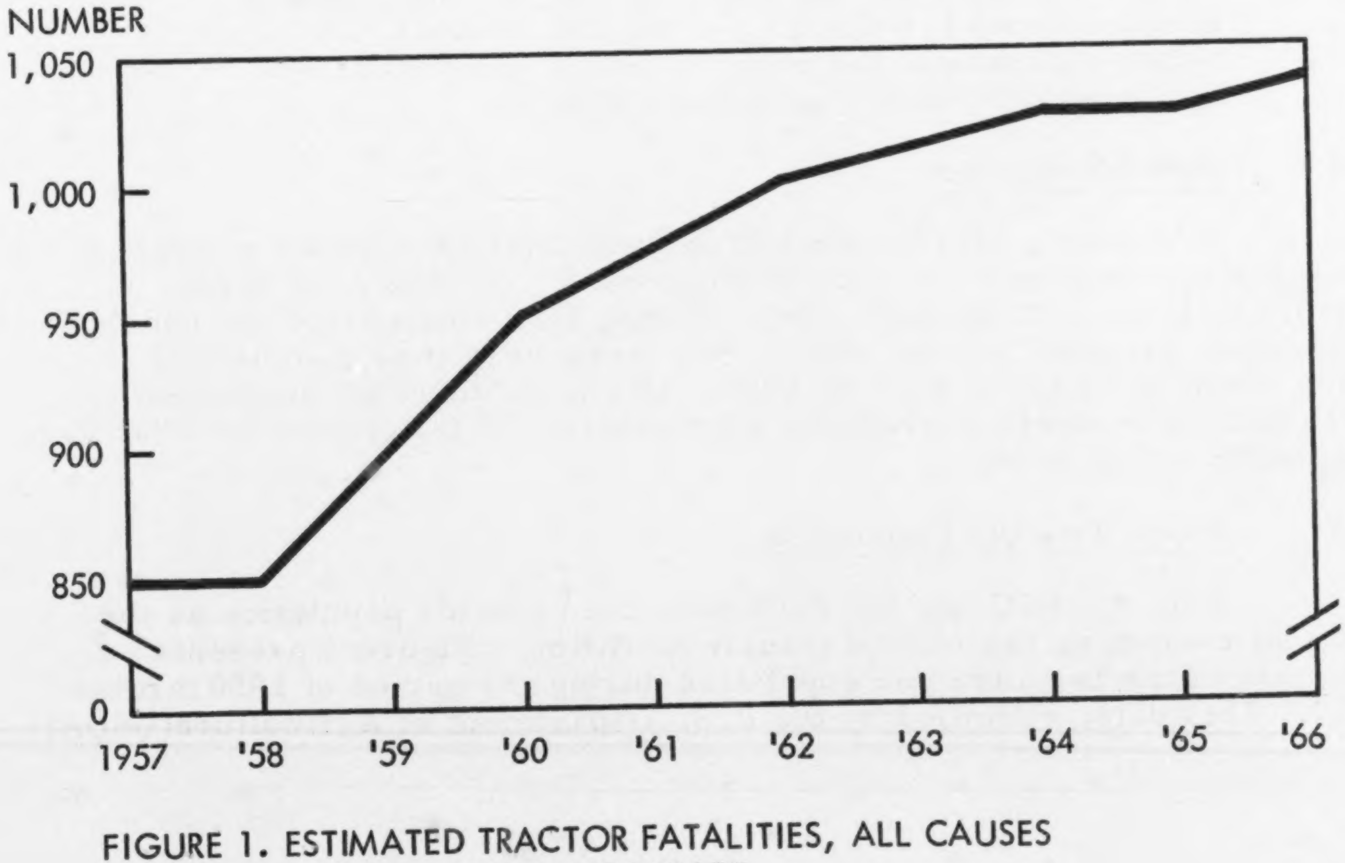


FIGURE 1. ESTIMATED TRACTOR FATALITIES, ALL CAUSES
SOURCE: NATIONAL SAFETY COUNCIL.

shows that the current tractor population is estimated at 4.8 million tractors, slightly lower than the estimated 1959 peak population of almost 5 million.

Since 1959, there has been a slight decrease in the number of farm tractors, and although it is not shown in Figure 3, the USDA Economic Research Service projects a continued decrease in the number of farm tractors over the next five years. Forecasts are shown at Appendix C of this report.

2.4 Tractor Characteristics

Certain tractor characteristics appear to have a direct or secondary effect on both the tractor population and number of tractor fatalities. These include the tractor age, type of fuel, horsepower and wheel arrangement. The relationship of each of these characteristics to the number of fatalities will be discussed in more detail in later chapters as well as in the technical papers presented in Appendix A of this report. In each of these relationships, it is not only important to present information on today's tractor population, but also on trends. Unfortunately, data are incomplete and fragmentary in most areas and the following should be considered as best estimates based on currently available information.

2.4.1 Tractor Age

Age of the tractor is important primarily because more modern tractors have certain safety features designed into them which are not in the tractor models built during the 1940's and 1950's.

Figure 4 shows the tractor population in each 5-year age group based on 1969 tractor age estimates provided by the USDA Economic Research Service. The Figure shows, for example, that 817,000 tractors are from 1 to 5 years old and that the largest group of tractors in operation today (1,300,000) is from 16 to 20 years old. Data from the USDA Economic Research Service also indicates that in 1969 the average tractor was 14.3 years old. Data from other sources indicate that approximately 160,000 tractors are sold domestically each year. Based on a total tractor population of 4.8 million, this represents an annual replacement rate of approximately 3.3 percent.

2.4.2 Type of Fuel

Type of fuel is of significance because the fuel flash point determines to some extent the fire hazard; that is, gasoline is more likely to ignite than diesel fuel. Also, the operating characteristics of diesels are such that the diesel engine does not respond as quickly when shut off as does a gasoline engine. Gasoline engines are normally shut off by interrupting the ignition, while diesels are normally turned off by shutting off the fuel supply. The gasoline engine responds

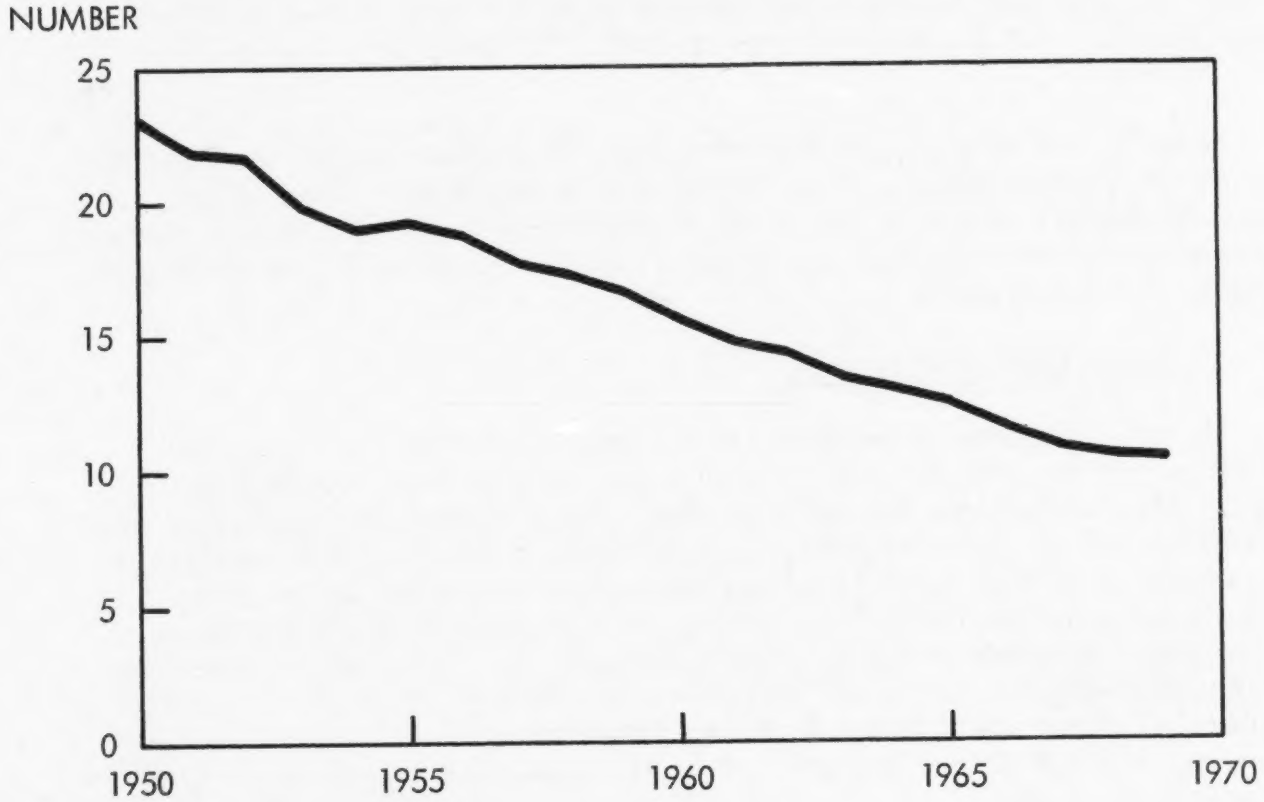


FIGURE 2. FARM POPULATION, 1950-1970 (MILLIONS)
DATA SOURCE: U.S. DEPARTMENT OF COMMERCE, BUREAU OF THE CENSUS.

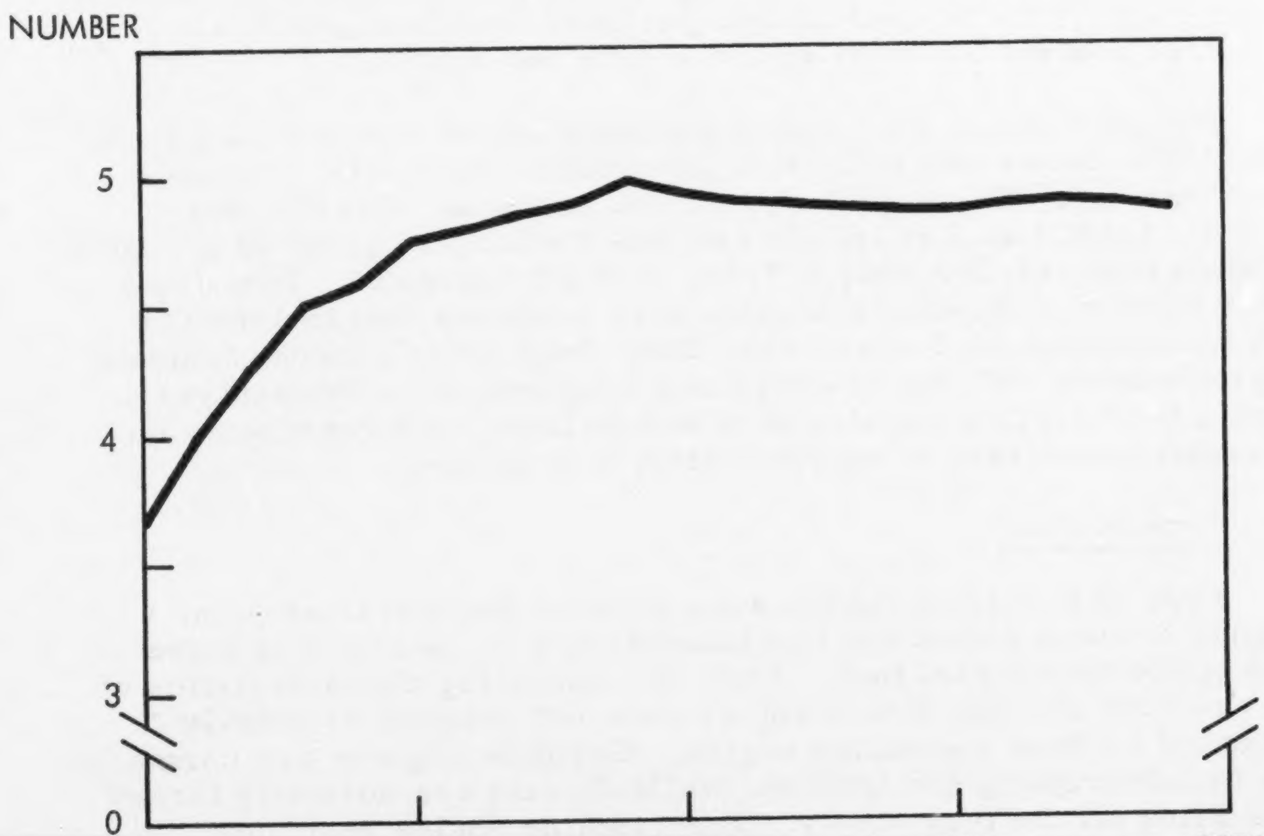


FIGURE 3. TRACTOR POPULATION, 1950-1970 (MILLIONS)
DATA SOURCE: U.S. DEPARTMENT OF AGRICULTURE, ECONOMIC RESEARCH SERVICE.

relatively quickly, while the diesel engine stops when the fuel remaining in the lines is consumed.

Table 2 is an estimate of the distribution of tractor population by types of fuel. The data shows that from 1960 to 1970, the percentage of tractors using diesel fuel has increased from 9 to 28 percent and, if one considers that only 3.3 percent of the total tractor population are replaced every year, this increase indicates that most new tractors are diese fueled. Domestic tractor manufacturers confirm the shift from gasoline to diesel in broad estimates which range from "most tractors" to "almost all tractors produced today are diesel powered."

2.4.3 Horsepower and Front End Design

In the past 20 to 25 years there has been a steady increase in the average horsepower of new tractors. Figure 5, based on data provided by the USDA Economic Research Service, indicates that the average horsepower of new tractors has increased from 41 to 75 horsepower in the last 15 years.

Similar data were sought on the wheel arrangement of tractors, that is, whether the tractor is of the tricycle type (three point) or is designed with an adjustable front axle (sometimes referred to as wide front end). Data are not available on which to base even a crude estimate of how many of the 4.8 million tractors are tricycle types. Two of the leading tractor manufacturers have indicated, however, that in 1969 between 85 - 90 percent of the production was in wide front axle tractors while, in 1959, between 85 - 90 percent of the production was tricycle type design.

The increase in tractor horsepower and the shift from tricycle to wide front-end design is important from the standpoint of side overturn, which is discussed in more detail in Section 3.1.

2.5 Tractor Involved Injuries

None of the sources reviewed for this report shows estimates of the total number of tractor involved non-fatal accidents or injuries in the United States. Disabling injury data for farms or agriculture include all farm machinery or all work on the farm or, in certain independent studies, non-fatal highway accidents involving farm tractors in a single State.

Darrell L. Roberts and Charles W. Suggs conducted a study of North Carolina fatal and non-fatal highway accidents and noted the following:

> ". . . 1589 of the highway accidents occurring in North Carolina during 1962-66 involved farm vehicles, and of these 595 were injurious, exclusive of

TABLE 2 --- DISTRIBUTION OF TRACTOR POPULATION, BY TYPE OF FUEL AS OF DECEMBER 31, 1960 AND 1970

	1960	1970
GASOLINE	85 %	67 %
DIESEL	9 %	28 %
ALL OTHER*	6 %	5 %
TOTAL PERCENT	100 %	100 %
TOTAL NUMBER	4,930,000	4,801,000

* MOST OF THESE ARE LPG FUEL, WITH THE REMAINDER USING KEROSENE, DISTILLATE AND POWER FUEL.

DATA SOURCE: U.S. DEPARTMENT OF AGRICULTURE,
ECONOMIC RESEARCH SERVICE, MR. PAUL STRICKLER.

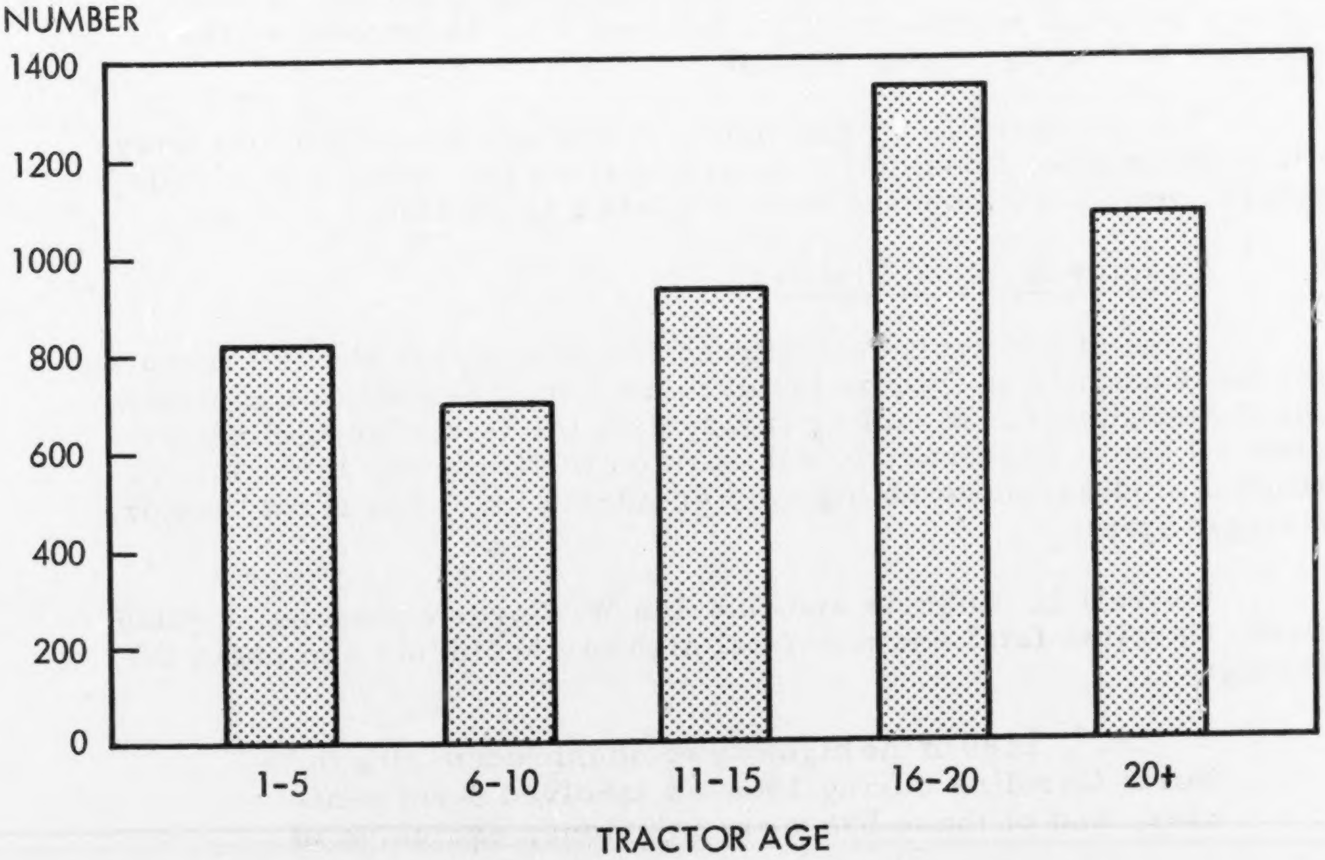


FIGURE 4. TRACTOR POPULATION BY AGE OF TRACTOR, 1969
DATA SOURCE: U.S. DEPARTMENT OF AGRICULTURE, ECONOMIC RESEARCH SERVICE.

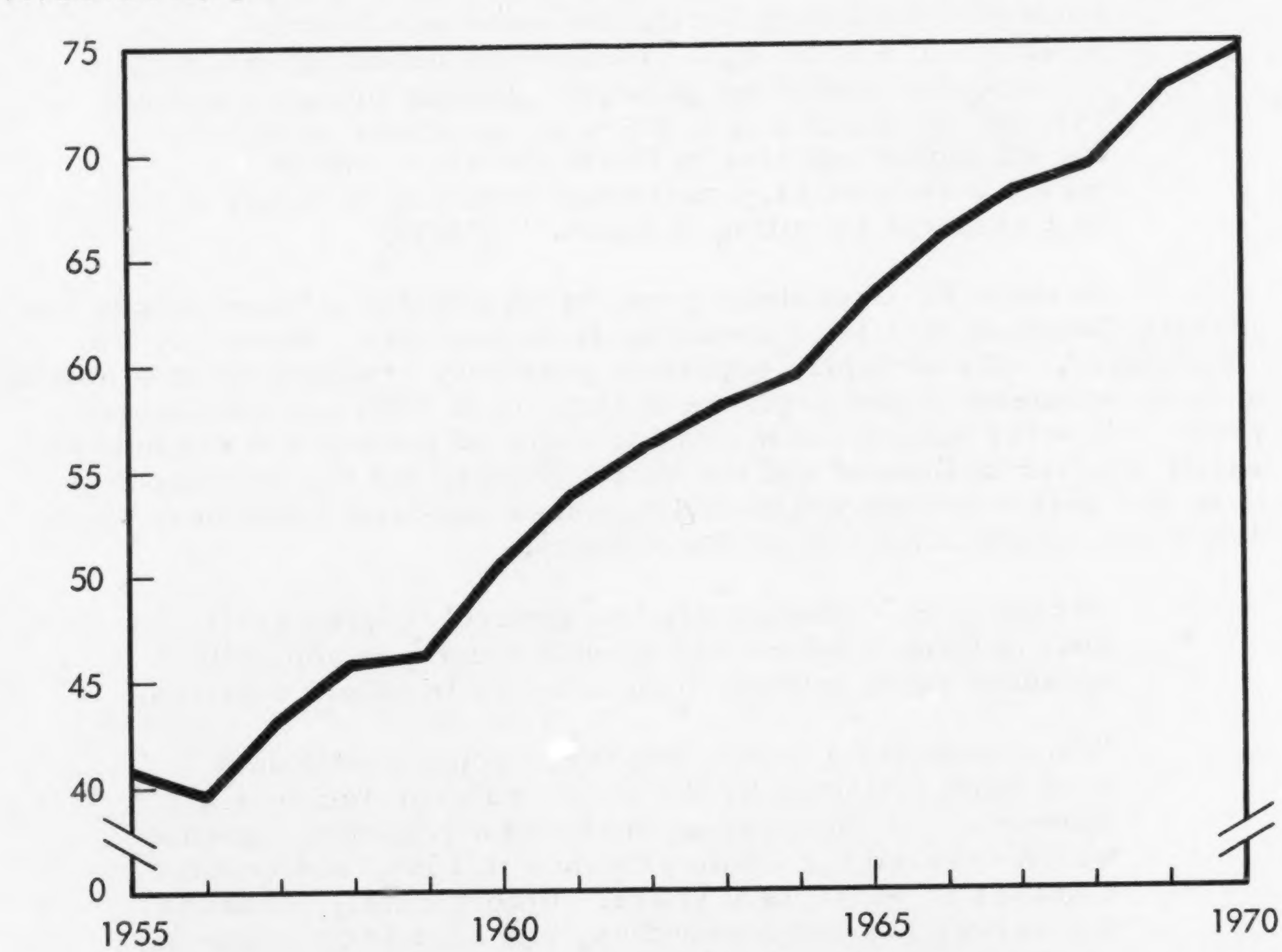


FIGURE 5 AVERAGE H.P. OF TRACTOR SHIPMENTS.
DATA SOURCE: U.S. DEPARTMENT OF AGRICULTURE, ECONOMIC RESEARCH SERVICE

> fatalities, to one or more persons. With 73 fatal accidents occurring during the same period this would yield a ratio of 8.15 accidents resulting in injury to 1 accident resulting in death. During the same period 137,438 injurious and 6,465 fatal accidents occurred for all motor vehicles in North Carolina, which yields a ratio of 21.3 accidents resulting in injury to 1 accident resulting in death." (126:5).

Graham F. Donaldson remarks on similar circumstances regarding Canadian statistics involving farm tractors. However, he comments briefly on injury statistics generally resulting from a survey of farm accidents in the province of Ontario in 1959 and subsequent years. Tractor use, farm terrain and type of tractor are not necessarily similar in Canada and the United States, but the data appears to be the best available which encompasses non-fatal machinery accidents both on the farm and on the highway:

> "There are, consequently, no general figures available in Canada which will permit a comparison with accident rates in other industries or in other countries.
>
> "On a provincial basis, however, some useful data have been collected by the Ontario Farm Accident Survey . . . . This survey involved a reporting scheme which covered the whole province in 1959, and certain counties in subsequent years. Unfortunately, because the survey has not covered any one area for a sequence of years, the data do not show any trends in the frequency or pattern of farm accidents. The survey does, however, provide some information about the nature of farm accidents and it gives an indication of the relative frequency of accidents causing temporary injuries, permanent injuries, and fatalities respectively.
>
> "Figures from the individual counties in 1959, and from those surveyed in subsequent years, show a steady relationship between the number of machinery accidents involving fatal, permanent and temporary injuries. Fatal machine accidents vary from two to six percent of all accidents, while those involving permanent injury make up from 11 to 22 percent of the total, and temporary injuries comprise from 75 to 85 percent of the effects in all cases.
>
> "A separate survey conducted in Quebec and Manitoba by 4H Clubs provided data which were later summarized for Canada by the Canadian Chamber of Commerce. These figures show for Quebec four, eight, and 88 percent respectively, and Manitoba four, three and 93

percent respectively for fatal, permanent and temporary injuries. With slight differences, possibly due to differences in classification criteria, these figures are comparable with those for Ontario." (23:22-23).

2.6 Location of Fatal Accidents

According to data compiled by the NSC (see Table 1) an average of approximately 230 fatalities involving farm tractors have occurred annually on the nation's highways over the past 5 years. The NSC estimate of 1,000 total farm tractor fatalities implies that the balance of 770 (1,000-230) occur on the farm -- or at least off the highway. This yields a ratio of approximately 3.3 farm fatalities to each highway fatality. The 5-year averages for Nebraska, North Carolina, and Ohio data shown in Table 1 indicate, farm to highway fatality ratios of 2.8 to 1, 3.1 to 1, and 2.5 to 1, respectively. If we assume that the NSC count of 230 farm tractor fatalities on highways is accurate and that the farm to highway fatality ratio is 2.8 to 1 (the average ratio of the three above States) rather than 3.3 to 1, then an estimate of 640 farm fatalities is indicated, with a total fatality estimate of 870 (230 + 640). This is within the previously noted estimates of 800 to 1,000.

In summary, it appears reasonable to assume that 230 tractor fatalities occur annually on the highways and an additional 650 to 750 occur on the farm.

2.7 Breakdown of Fatal Accidents by Accident Type

An analysis was made of available tractor fatality data to determine the manner in which the fatal accident occurred. W. E. Stuckey, of Ohio State University reports the distribution of Ohio fatalities as shown in Table 3. (158).

Rollin D. Schnieder of the University of Nebraska presents the distribution of Nebraska fatal tractor accidents shown in Table 4. Professor Schnieder's data is based on a 5-year newspaper clipping survey of agricultural accidents in Nebraska, 1965 through 1969.

Data from the Kansas State Department of Health indicates that for the past 5 years, the distribution of tractor fatalities is as presented in Table 5. (65).

Two things are evident from Tables 3, 4 and 5. First, tractor overturn is the predominant type of tractor accident involving a fatality. The indicated percentages range from 52 to 62 percent. Second, there is considerable variation, or at least an inconsistency, in the manner of reporting other types of fatal accident data. Some of the variation may be explained by differences in the terrain, types of farming and other environmental differences from one State to another; however, it appears that there is some lack of homogeneity in definitions and classifications of accident types as well.

The NSC analysis of 789 farm tractor fatalities is shown in Table 6.

2.8 Tractor Overturn

Several studies have been devoted solely to an analysis of tractor overturn accidents, since data indicate that this is the

TABLE 3 OHIO FATALITY DATA

ACCIDENT TYPE	1956-62	1963-69	14 YEAR TOTAL	14 YEAR PERCENT
Overturns	166	159	325	62
Non-Overturns	115	87	202	38
TOTAL	281	246	527	100

TABLE 4 NEBRASKA FATALITY DATA

ACCIDENT TYPE	n	Percent
Tractor Overturns	107	59
Run Over by Tractor	42	23
Power Takeoff (PTO)	11	6
Thrown From Tractor	9	5
Miscellaneous Tractor	12	7
TOTAL	181	100

TABLE 5 KANSAS FATALITY DATA

ACCIDENT TYPE	n	Percent
Tractor Overturn	61	52
Fall From Tractor	27	23
Runover by Tractor	14	12
Other	15	13
TOTAL	117	100

TABLE 6 NATIONAL SAFETY COUNCIL ESTIMATES

ACCIDENT TYPE	Percent
Tractor Upset	58
Fall From Tractor	13
Crushed (other than run over)	9
Runover	8
Motor Vehicle Collision	6
Power Takeoff	3
Other	3
TOTAL	100

predominant type of fatal tractor accident. One such study of overturn protection was conducted by Rollin D. Schnieder and Robert J. Florell of the University of Nebraska Cooperative Extension Service under a grant from the NSC. Schnieder and Florell analyzed 100 tractor overturn accidents which occurred in Nebraska during 1966, 1967, and 1968. The sample population for the study was the first 100 accidents reported by a Statewide clipping service, 42 of which resulted in fatalities.

The report presents data on the age level of victims by accident location, tractor speed, degree of injury and operator's degree of experience; the degree of overturn by severity of injury; and other classifications of pertinent data. However, the two parameters of particular interest to the NHSB in presenting this overview of tractor safety are the direction of overturn and whether the tractor was the tricycle or the wide front-axle design. The Schnieder and Florell data are shown in Table 7 and the report indicates that 67 percent of the tractors were of the tricycle type. (139:10, 12).

W. E. Stuckey of the Ohio State University in his analysis of 459 Ohio fatalities between 1956 and 1969, reports the distribution of Ohio tractor overturn fatalities shown in Table 8. The Ohio report shows the fatal overturn accidents in that State equally divided between the wide front-axle and the tricycle type tractors.

The results of another study of tractor overturns were presented at the 1969 winter meeting of the American Society of Agricultural Engineers by F. R. Willsey and K. B. Liljedahl of Purdue University. The study was conducted under a grant from the U.S. Department of Health, Education, and Welfare. The analysis was restricted to non-fatal overturn accidents. It involved 145 cases, and its purpose was to obtain information on overturn prevention using information obtained from interviews with accident survivors. The distribution of non-fatal overturn accidents by roll direction and tractor type is presented in Table 9. (193).

All of the above studies agree on the predominance of side upsets over backward upsets by factors of 6, 2, or 5 to 1, respectively. It should be noted also that the above three sources estimate that overturns to the back comprise 13, 30, and 14 percent, respectively, of overturn fatalities. While occurrence of the backward type is not as frequent as sideways, nevertheless, it is still significant among fatal tractor accident characteristics.

The above sources report that the tricycle type tractor was involved in 67, 50, and 76 percent, respectively, of overturn accidents. The significance of this factor is difficult to measure since data are not available for the population distribution between tricycle and wide front-axle tractors. The tricycle tractor may be involved in more side overturn fatalities simply because there may be more tricycle tractors than wide front-axle tractors. The wider stance of the wide front axle tractor suggests greater stability and less susceptibility to side overturn than the tricycle type. It is encouraging to note that current tractor production now favors the wide front-axle tractor by a wide margin.

TABLE 7 NEBRASKA DATA ON ROLL DIRECTION

ROLL DIRECTION	n	Percent
Side	86	86
Backward	13	13
Forward	1	1
TOTAL	100	100

TABLE 8 OHIO DATA ON ROLL DIRECTION

ROLL DIRECTION	n	Percent
Side	210	65
Backward	97	30
Forward	13	4
Unknown	5	1
TOTAL	325	100

TABLE 9 PURDUE DISTRIBUTION ON NON-FATAL ROLLOVER ACCIDENTS

	TYPE OF TRACTOR		
ROLL DIRECTION	TRICYCLE	4 WHEEL	TOTAL
	(Percent)		
Side	64.1	18.6	82.7
Backward	9.7	4.8	14.5
Forward	2.8	-----	2.8
TOTAL	76.6	23.4	100

2.9 Age of Victim

Tractor accidents have involved victims literally of all ages. The NSC study shows tractor fatalities ranging in age from less than 5 years to seventy and over. This range in age among tractor fatalities is typical of the range in other reports reviewed here.

The distribution of tractor fatalities by age group in comparison to age of the farm population is presented in Figure 6. Although the NSC study shows one victim less than 9 years of age who was driving the tractor, practically all of the fatalities occurring to children under 9 years of age were tractor passengers or pedestrians. However, the number of fatalities within the under 15-year age group is about the same as for the 15-24 age group. The highest accident rate is among the 45 and older members of the farm population. Evidence suggests that most of the victims in this age group are tractor operators.

A more detailed discussion of the relationship between age of victim and age of tractor operator in tractor accidents is presented in Chapter 4.

2.10 Sex of Victim

Male victims comprised 97 percent of the NSC study sample. According to the NSC report, "The number of female victims in the study sample was so small that differences, if any, in the characteristics of accidents involving males or females cannot be determined. However, nearly half the female victims were under 15 years of age". (105:3). None were over 74. A more detailed discussion of sex of tractor accident victims is presented in Chapter 4.

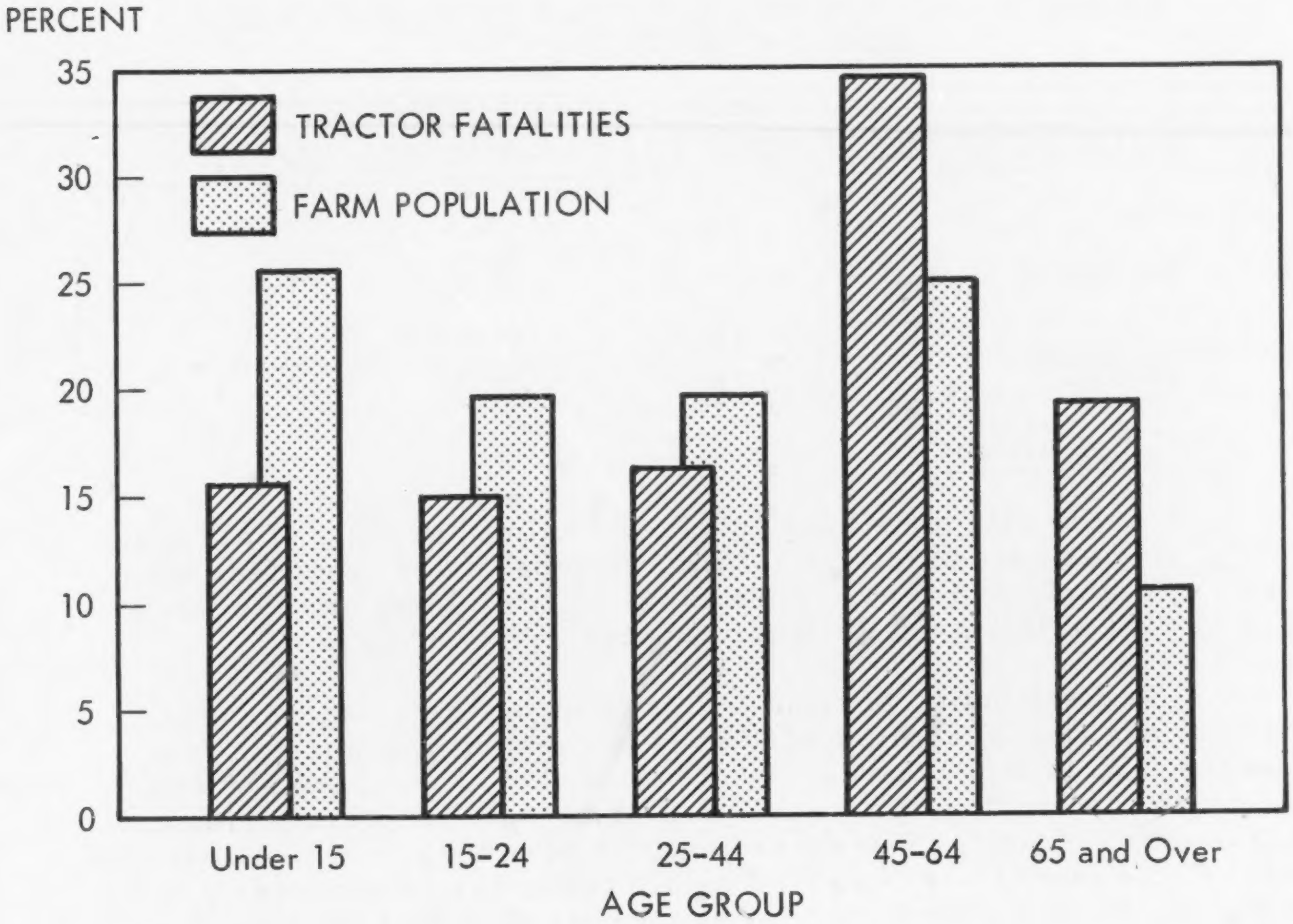


FIGURE 6 - COMPARATIVE DISTRIBUTIONS OF TRACTOR FATALITIES VS. FARM POPULATION, BY AGE.

NOTE : CENSUS BREAKS FIRST TWO AGE GROUPS AT AGE 14, WHILE NSC BREAKS THEM AT AGE 15.

DATA SOURCE: FATALITY DATA ARE FROM NSC, 1960-65; POPULATION DATA ARE FROM U.S. DEPARTMENT OF COMMERCE, BUREAU OF THE CENSUS, 1969.

2.11 Concluding Statement

Based on the fragmentary data available involving farm tractor accidents, fatalities, and injuries, the following approximate estimates and observations can be made:

- Between 800 and 1,000 fatalities result annually from tractor involved accidents.
- Sixty percent of the fatalities resulted from the tractor overturning
- More than two-thirds of the fatal tractor accidents occurred on farm property; of those occurring off farm property, one-third involved motor vehicles.
- The most reliable estimates involve fatalities, not injuries.
- Tractor accident data have not focused sufficiently on factors such as accident type; injury type; make, model and age of tractor; and on important human factors. This information is essential to obtain an accurate portrayal of the overall tractor accident situation, and to develop a data base upon which industry, government and others can draw when developing countermeasures.

CHAPTER THREE

3. 0 Tractor Caused Accidents and Injuries

For convenience in approach, identification of the primary causes of agricultural tractor accidents and the hazards most likely to cause death and injury, will be considered in terms of the tractor (vehicle), the human (operator) and the environment (physical conditions). This approach is obviously arbitrary since most if not all vehicle accidents involve an interaction or interplay among these three factors. Its merit lies in permitting the many elements of a complex problem to be sorted out and evaluated. Further, it provides a framework for the development of a range of remedial measures that would reduce the number and severity of tractor accidents.

This chapter relates the elements of tractor design and operation to accidents and injuries. The vehicular elements and operating factors of primary concern are:

- Tractor overturn
- Power takeoff (PTO) accidents
- Health hazards
- General design features

3. 1 Tractor Overturn

Approximately 60 percent of the fatalities resulting from tractor accidents are the result of tractors overturning to the side, to the rear or to the front. An understanding of various aspects of the overturn phenomenon is necessary because of their preponderance and severity:

- Mechanics of overturns
- Conditions of overturns
- Design features affecting overturns
- Overturn countermeasures

3.1.1 Mechanics of Tractor Overturns

Overturns in the field are due basically to the location of the center of gravity (CG) of the tractor and the geometry of the wheel contact with the ground. As stated in Operating Farm Tractors and Machinery, "A tractor tips when some force or condition moves the plumb line from the center of weight of the tractor, outside the tractor's base of stability. This base of stability is formed by connecting the outside points of contact of the tractor wheels." (187:65) (Figure 7).

A. Vertical Center of Gravity

The height of the center of gravity (CG) has a major effect on the stability of the farm tractor. The higher the CG, the more unstable the tractor can become with any movement of the tractor . This can be understood by considering a tractor at a given angle of inclination. As the CG is raised, the nearer the plumb (vertical) line from the CG approaches the limits of the base of stability, thus reducing the margin of stability. Also, since the inertia force acts through the CG, the higher the CG the longer the moment arm and the greater the overturning moment.

The University of Nebraska Test Center has been conducting tests on tractors since about 1919, and reporting the location of the CG since about 1960. These test reports support the understanding gained from tractor design engineers that the CG has not changed substantially over the years. This is attributable to the formidable versatility requirements for tractors imposed by the wide range of farm operations. Important among these requirements is that of high ground clearance to clear crops during tillage.

B. Longitudinal Center of Gravity

When the longitudinal CG is located toward the front of the tractor it increases rearward stability but decreases the sidewalk stability, especially on tricycle type tractors. The operator can adjust the longitudinal CG of the tractor if desired by adding weight to the front or by adding wheel weights to the rear drive wheels. Adjustments can also be made by partially filling the drive tires with ballast or by adding dual drive wheels. Any ballasting of the rear rims and tires, or the addition of dual rear tires, however, does make the tractor more susceptible to rear overturns because it increases the inertia of the wheels and consequently the drive-axle torque necessary to start the tractor moving. Carrying attachments on the rear of the tractor or a bucket loader on the front also affects the location of the CG. Hence, while moving the longitudinal CG is advantageous in certain situations, moving it either way may have an adverse effect on either the rearward or sideward stability. Again the longitudinal center of gravity appears to have remained the same in two-wheel drive tractors since 1940.

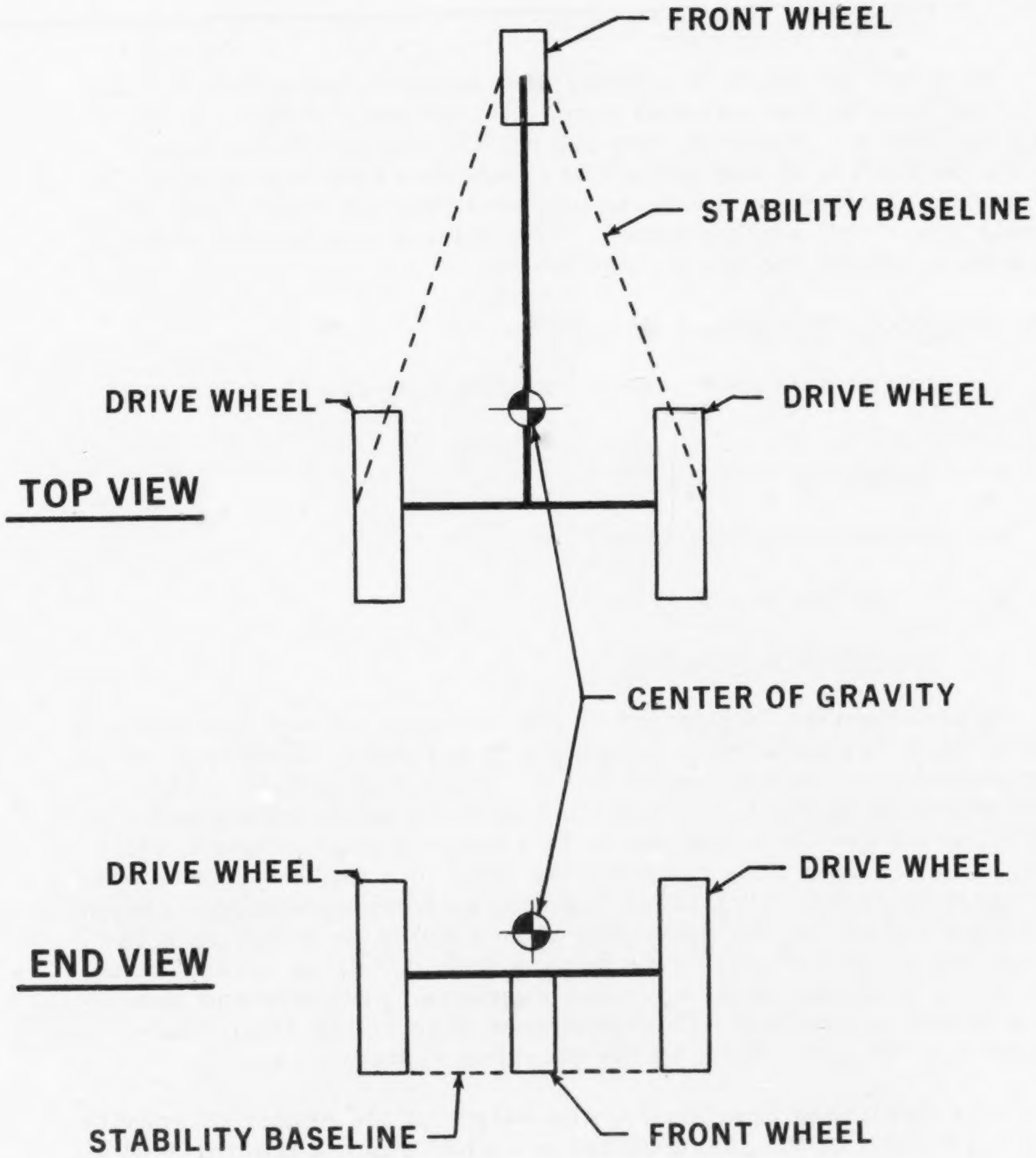

FRONT WHEEL
STABILITY BASELINE
DRIVE WHEEL
DRIVE WHEEL
TOP VIEW
CENTER OF GRAVITY
DRIVE WHEEL
DRIVE WHEEL
END VIEW
STABILITY BASELINE
FRONT WHEEL

Figure 7. Diagram of stability baseline

C. Lateral Center of Gravity.

The lateral center of gravity of tractors is generally located on the center line of tractors and is not considered a major factor in overturn accidents. However, the lateral CG can be moved to one side by the ballasting of one drive wheel and this can help to cause a side overturn. In fact, a side overturn accident has been reported where only one wheel was weighted. The tractor overturned when making a turn toward the unweighted wheel.

3.1.2 Conditions of Tractor Overturns

As stated previously, there are three types of tractor overturns:

- Overturns to the side
- Overturns to the rear
- Overturns to the front

A. Overturns to the Side

Approximately 75 percent of all tractor overturn fatalities is believed to have resulted from overturns to the side. This type of overturn can occur in a number of ways. In the field, they result when one wheel is suddenly and substantially elevated or dropped, such as occurs when the wheel drops in a hole or goes over a large obstacle, or when operating too near the edge of a highway, drainage ditch or steep hillside. Overturns may occur when operating on level ground with a bucket loader attached; when a bump or rough spot is struck which causes the tractor to bounce with resulting loss of control; or, when steering brakes are not connected properly and one wheel locks during braking. Overturns can also result from malfunction of tractor parts such as the steering system.

As established previously, the height of the center of gravity makes a difference in the circumstances under which a tractor will turn over. It has been noted that as the center of gravity shifts to the rear, the tractor becomes more stable against side turnover, but this in turn will decrease rearward stability. Also, the wider the wheels are spaced, the more sideward stability the tractor will have. The addition of a wide front axle also will increase stability.

Some accidents occur on the road as a result of turning too sharply for a given speed. As reported in the Operating Farm Tractors and Machinery Book "The chances of upsetting on a turn are four times greater when speed is doubled." (187:45).

Other overturns, particularly those on roads, result from traveling at too high a rate of speed. Some overturn accidents occur as a result of coasting down a hill out of gear. Careless operation can result in excessive speed and loss of control of the tractor. These types of overturns and design features which affect them are discussed in more detail later in this chapter.

Side overturns also result from tractors towing trailers that are without brakes. Relevant to this, Schnieder says, "We must realize that some of the towed equipment such as the anhydrous ammonia tank might weigh close to 8,000 lbs. If these do not have braking systems and must be stopped immediately, jackknifing can occur and result in overturning or a more serious type of accident. Many of the tanks that are being made lend themselves to this type of overturn since they might also be 3 wheeled tanks or a tricycle type tank." (Appendix A:A14).

B. Overturns to the Rear

The number of fatalities per year resulting from rear overturns is about one-third the number of side overturns. The rear overturn is described in Operating Farm Tractors and Machinery as follows: "A tractor will tip when it takes less power to lift the front end than it does to move the load or slip the wheels. The power needed to lift the front end of a tractor is proportional to the distance from a point located by dropping a plumb line from the center of weight of the tractor to a point even with the first point of contact of the drive wheels with the ground or other surface which it is on. Thus, the steeper the hill or the deeper the wheels dig in, the easier the tractor will tip over backward." (187:65).

The tractor, depending upon conditions, can rotate either about the center of the rear axle or the point of contact of the rear wheels with the ground.

Some examples of rear overturns are discussed by Wardle:

1. "The tractor encounters soft ground, the drive wheels dig in and may become lodged or slip easily. Whether this is on the level or not is of little consequence. The rear end drops down and the operator then often disengages the load. If the wheels slip the operator may block or chain the wheels to prevent the slippage. The operator then shifts to low gear, guns the motor, and jams in the clutch. Within a split second, the combined force of full engine power and stored fly-wheel energy raises the front of the tractor, it overbalances and tips over backward." (Appendix A:A54).

2. "The tractor is going up a steep incline or pulling out of a ditch. It is started by gunning the motor while in a low gear, and the clutch is jammed in too quickly." (Appendix A:A55).

3. "The load is attached to the axle or to a drawbar which has been raised too high or cut or set too short. The hitch on the tractor should not be tampered with to change it. The adjustments provided can be used, but it should not be rebuilt to raise its height or to shorten it." (Appendix A:A55).

Wardle lists these practices which may cause or prevent overturns to the rear: (Appendix A:A61).

These Increase Backward Tipping	These Decrease Backward Tipping
Driving up an incline	Driving down an incline
Wheel weights	Front weights
Ballast in tires	Lowering hitch with load
Mounted load	Properly hitched load
Raising hitch with load	Reversing when wheels are frozen
Rear wheels digging in	Reversing when rear wheels are in a ditch or in a hole
Using forward gear when rear wheels are frozen	
Driving forward when rear wheels are in a ditch or hole	

C. Overturns to the Front

Very few of the overturn accidents are of the forward type. There is little information on these accidents and therefore it is difficult to determine their causes. With the CG located so far to the rear on farm tractors, it is difficult to understand the forward overturn unless the tractor had an attachment such as the bucket loader and was traveling downgrade at the time.

3.1.3 Design Features Affecting Tractor Overturns

Tractor design features which affect the frequency and type of overturn accident are as follows:

- Location of wheels
- Spacing of the rear axle
- Dual wheels
- Suspension

- Power train
- Brakes
- Steering
- Wheelbase
- Hitchpoint

A. Location of Wheels. There are two general types of wheel layouts for tractors differing only in the front wheel layout -- the wide front-end type and the tricycle type. The tricycle type may have one front wheel or two front wheels spaced close together to serve essentially as a wheel point.

The front-end wheel arrangement does not have any effect on rear overturns except as it may affect the center of gravity, nor does it have much of an affect on forward overturns except that with a tricycle type tractor what might otherwise be a forward overturn probably would develop into a side overturn.

With regard to the side overturn, Coleman says:

> "This configuration [wide adjustable front-end] * has improved safety relative to a side overturn for two reasons: One, it cannot turn as short as the Super 'M' [a tricycle type tractor], . . . and two, the wide adjustable front axle with its center pivot provides restraint to tipping in a short turn. Under these conditions, the tractor can tip only a limited amount and then pivoting of the front axle is stopped, and the tipping axis moves out and is on a line which connects the outer edges of the front and rear tires. With the tricycle tractor, no such intermediate restraint exists; the tipping axis is on a line connecting the outer edge of the rear tire to the outer edge of the front tricycle wheel." (Appendix B;B79).

Schnieder comments thusly:

> "The tricycle-type tractor will overturn more easily than the wide front-end tractor. However, many things must be taken into consideration, because under certain conditions the wide front-end tractor can overturn just as easily." (Appendix A:A12).

B. Spacing of the Rear Axle. Obviously, the wider the rear axle spacing, the more resistant the tractor is to side overturns.

---

* Editorial comment.

The spacing effect on other types of overturn is negligible. Coleman states: "Our tractors today have improved safety by virtue of their being used at wider tread settings." (Appendix B:B80).

In 1940, the maximum rear tread width listed in the Red Book Issue of Implement & Tractor magazine was 90 inches. The 1970 issue of this same publication lists 120 inches as the maximum tread width. Data are not immediately available to permit comparison of present day rear-wheel spacings and CG's with those of earlier tractors.

C. Dual Wheels. Rear dual wheels are becoming popular in many areas, supposedly because of their increased traction and lower ground pressure. As pointed out earlier, duals increase the side and forward stability by widening the base of stability and shifting the CG to the rear. However, duals also decrease the rearward stability by this shift in CG, by increasing the inertia of the rear wheels and by providing greater traction.

D. Suspension. The only suspension system available on farm tractors is the large rubber tires which act as a spring system with very low damping. This springing action with such minimum damping can give a tractor a pronounced bounce and can place the tractor in an unstable condition. Thompson states, "Agricultural tractors operating on a slope can be statically stable but dynamically unstable and tip over rearward or sideward. The dynamically unstable condition is due to the angular momentum gained by the frame from the impulse produced by the tire." (170:1). Pershing and Yoerger also point out that a tractor can become unstable on level ground when hitting a certain five-inch high bump. (118:718). Wardle claims, "A tractor can tip over sideways at a speed of 8 mph if the wheels drop into a hole or hit an obstruction (8 mph is about twice as fast as you can walk). It will tip at a much slower speed if you are turning." (Appendix A:A54).

There is little that can be done to offset this almost undamped spring characteristic since large wheels must be used for low ground pressure mobility and traction as well as high ground clearance. As Schnieder says, "A tractor going on a graveled or dirt roadway begins to bounce if speeds are too fast and the front end does not have good contact with roadway. When this occurs, it is easy for the tractor to go out of control." (Appendix A:A24).

E. Power Train. The power train of a tractor determines its speed and amount of torque available at the drive axles. It also determines the smoothness of power application. According to Schnieder, "The maximum speed of the farm tractor in most cases is too fast. Some models are capable of going at speeds up to 22 miles per hour. Fifteen miles per hour is fast enough. The only place where the 22 mile per hour speed is used is on transportation from one area to another. The difference of a few miles per hour will not make a big difference in moving time from one field to another, but it might mean the difference between life and death." (Appendix A:A23). Wardle has this to say regarding speed: "Speeds up to 15-20 mph are very advantageous when moving crops to market and when moving from one farm unit to another.... Of course, speeds above 20-25 mph should never be used with tractors. The tractor is too unstable for any speeds beyond this." (Appendix A:A63).

Speed is the big factor in overturns, particularly when turning too sharp. Wardle states, "A moving tractor tends to continue to move in a straight line." (Appendix A:A56). Wardle's paper also explains the dynamics involved in tractor overturns as a function of speed, incline, axle and radius of turn. (Appendix A:A57). Schnieder further states, "One other hazard in high speed operation is the gravel pile along the edge of the roadway. Many overturns have occurred where the rear wheel of the tractor was run into the gravel pile. This would pull the tractor into the ditch and the tractor would overturn. Once again, excessive speed leads to this problem. Some tires have ballast in the rear tires. This can be calcium chloride, other liquid solutions or it might be a barium powder mixture. If a tractor goes too fast, this material starts carrying over with the tire rather than seeking its own level. When this occurs, the tractor can begin bouncing and jumping and control can be lost." (Appendix A:A24).

Another power train characteristic which can contribute to accidents is the ability of the tractor to freewheel or jump out of gear. "Freewheeling" is more of an operator's choice as he can cause it either by depressing the clutch or putting the transmission in neutral. Sometimes a farmer will do this when driving down grade in order to gain more speed. However, when he does so, his chances of having an accident are increased not only because of this increased speed but because of the loss of braking through the power train. There are transmissions such as a hydrostatic tractor transmission about which Coleman says, ". . . whenever the ground speed of the hydrostatic tractor exceeds a speed previously selected by the speed ratio lever, automatic engine braking takes place, thus it is not possible for an operator to freely coast down a steep hill at excessive speed by simply actuating the pedal." (Appendix B:B85). With regard to the tractor jumping out of gear, claims are made that some of the newer transmissions will not do this, however, after these transmissions wear considerably they may still do so.

The design criteria for the amount of torque available at the rear wheels of a tractor is such that the tractor will spin its wheels under almost any condition of loading. If the tractor is not designed so, the farmer usually considers it underpowered and, therefore, may decide not to buy it. Unfortunately, this high torque capability makes it easier to turn the tractor over backwards under certain conditions.

A power train which provides for a smooth application of power is thought to be less susceptible to rear overturn. A rapidly applied clutch can cause the energy stored in the engine and flywheel plus the full engine torque to try to raise the front-end of the tractor before wheel resistance (including wheel inertia) and any drawbar load is overcome. Some accidents are believed to have occurred from operators "jumping" the clutch in such a manner.

F. Brakes. Brakes can be a factor in side overturns. As Wardle says,

> "Brakes are used on tractors for three reasons: (1) to assist in making short turns in field operations; (2) for emergency stops; and (3) for parking. Brakes have been involved in many accidents. For operational control in the field the brakes are made to operate independently with two brake pedals, one of which controls the brake on that side of the tractor. On practically all farm tractors, especially the wheel type, there is a means provided to lock the two brake pedals together for road operation and when short turning is not required. The idea being to apply the brakes equally to stop the tractor quickly without turning it. However, the continual individual use of the brakes results in uneven wear and when equal pressure is applied, as when they are locked together, there is unequal braking. This is a great contributing factor to side tips, especially overturn on the roadway and run off the roadway type of highway accidents." (Appendix A:A59).

Some of the newer tractors have power brakes which have a self-equalizing feature. As Coleman states it, ". . . equalization of left and right brakes is not dependent upon equal adjustment of both brakes. If both brakes are applied, the hydraulic pressure to both brakes is equal." (Appendix B:B81). It should be noted that there is still the possibility of the farmer forgetting to lock the brakes together, and applying only one brake.

Schnieder observes that the problem of braking occurs predominantly with trailing equipment such as the previously described anhydrous ammonia trailer. (Appendix A:A14).

Most manufacturers have protected against brake power failure by adding accumulators to store hydraulic pressure and by providing the capability of applying the brakes manually.

G. Steering. The steering ratio as set by the steering mechanism may be a factor in side overturns. The steering ratio is believed to be low so that the operator can maneuver the tractor with only small inputs to the steering wheel. Such a ratio, however, demands greater attention to the road when travelling on the highway for small movements of the steering wheel mean significant changes in direction of travel. If an operator is looking back to check traffic, he might inadvertently turn the steering wheel slightly and cause the tractor to run off the road. A low steering ratio can also be dangerous on models without power-steering, since the steering wheel can be jerked out of the operator's hands when a large obstruction is struck by one of the front wheels. For newer model tractors which incorporate power hydrostatic steering, this is reportedly not a problem.

H. Wheelbase. The wheelbase of a tractor is a factor in its rearward stability. The longer the wheelbase, the less effect the dropping of rear wheels into a ditch will have on moving the plumb line from the center of gravity of the tractor toward the rear axle. Also, the longer the wheelbase, the less effect bouncing of the wheels will have on the stability of the tractor on the road and the more stable the tractor will be for bucket loader operations. However, the longer the wheelbase, the less maneuverable is the tractor.

I. Hitchpoint. The hitchpoint is an important factor in rear overturns. It also has an affect on side overturns for if too much weight is carried on the hitch, the front wheels will become light and loss of steering control may result. If the hitch does not have a feature for preventing attachments from swaying freely, the tractor can become uncontrollable.

Operating Farm Tractors and Machinery reports "Any time you pull a load with your tractor, the load is trying to pull the tractor over backwards. . . The hitch on your tractor is designed to let you pull very heavy loads without fear that the tractor will upset backwards, provided you use the hitch properly." (187:43)

Schnieder says, "The design engineer does a good job of determining the point of pull or center of pull in the tractor as it leaves the plant If the tractor is used as designed to be used we would not have too many rear tractor overturns. Hitch point is designed to pull through the center of pull. If this is not done, backward overturns can occur." (Appendix A:A17).

There are different kinds of integral hitches. Depending on the tractor model, they may have one-, two-, or three-point connections between the rear mounted implement and the tractor. The single point hitch is essentially the drawbar hitch point. As discussed above, when the load is properly connected to the drawbar on level ground, the tractor will not turn over backwards. When the tractor is placed on a grade it becomes easier for the tractor to upset backwards and the steeper the grade the easier it becomes. Also if for some reason the drawbar is raised or shortened then it will be easier for the tractor to overturn rearward just as it would if the load were attached to a point such as the axle.

Two- and three-point hitches make a rear turnover more difficult than a simple drawbar connection. When an implement is attached to either hitch, it acts as an outrigger in back to stop the tractor from overturning to the rear. A schematic of a two-point hitch is shown in Figure 8 and a three-point hitch is indicated in Figure 9. Figure 10 is a photograph of a three-point hitch.

Schnieder says, "The development of the three-point hitch has saved many, many lives that would have resulted in backward overturns had it not been for the three-point hitch. " (Appendix A:A18). However, there is danger with both a two-point and a three-point hitch, for operators have been known to use the hitch as a single point hitch instead of the drawbar. If this is done with the hitch in the raised position, then, as Schnieder says" . . . we have a situation very similar to hitching to the axle and pivoting around the axle. . . . Even the three-point hitch with mounted equipment is not an entire safeguard if the operator does not use good common sense. We know of some situations where the linkage bars have been broken when the tractor came over backwards and the operator was pinned between the mounted equipment and the tractor itself. " (Appendix A:A17).

Of the three types of hitches discussed, the three-point hitch is by far the most frequent one in use.

3.1.4 Overturn Countermeasures

A. Training as a Countermeasure. A common misconception in the farming community is that an operator can leap off the tractor once he discovers that an overturn is imminent. Although there is some credence to this since most tractor accidents do not involve high speed, the rate of overturn once an overbalance condition has been reached is on the order of a second to a fraction of a second. At the same time, it is a difficult decision to be sure that the overturn is actually going to occur; otherwise, in leaping off, the operator may face the risk of being run over by the implement. In addition, many older tractors and some of the smaller new ones, have control levers, pedals, and the like concentrated in close proximity to the operator's feet, thus making it difficult for the operator to extricate himself from an overturning tractor.

Defensive training can help keep the operator from knowingly placing the vehicle in likely-to-overturn situations. However, there will always be the case where the operator's foot slips on the clutch, where one wheel suddenly drops while packing the silo travelling over rough ground, or where the tractor is moved off the road onto a steep

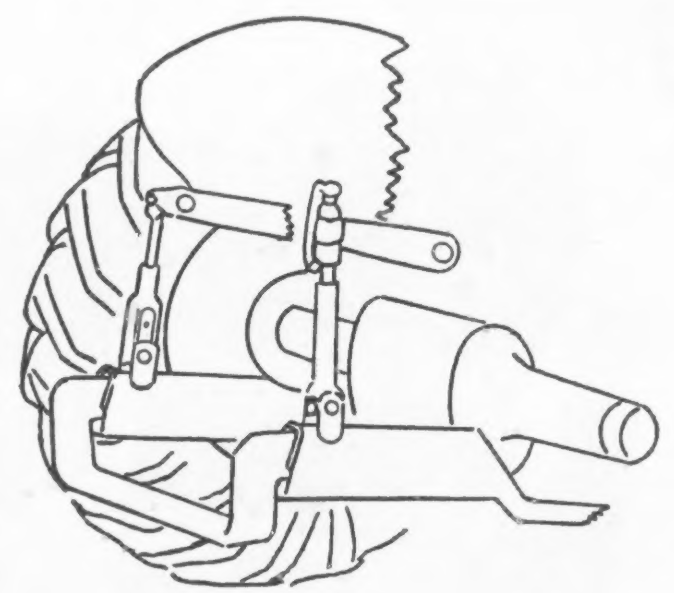
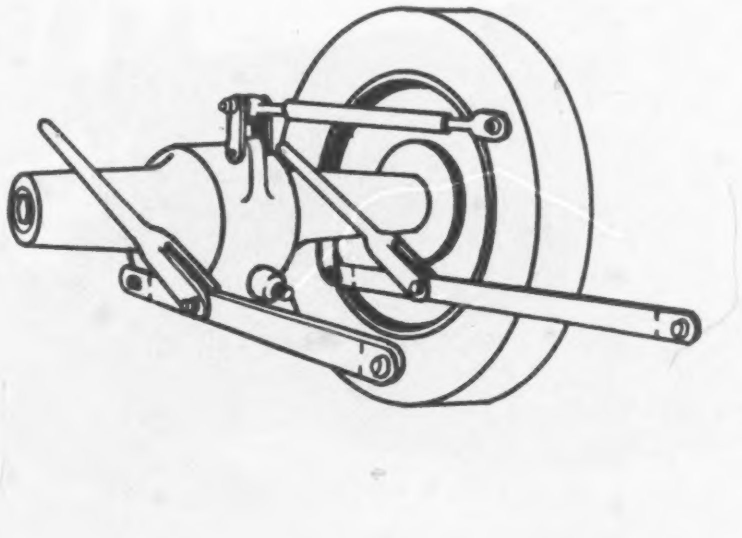


Figure 8.
Two-point hitch

Figure 9.
Three-point hitch



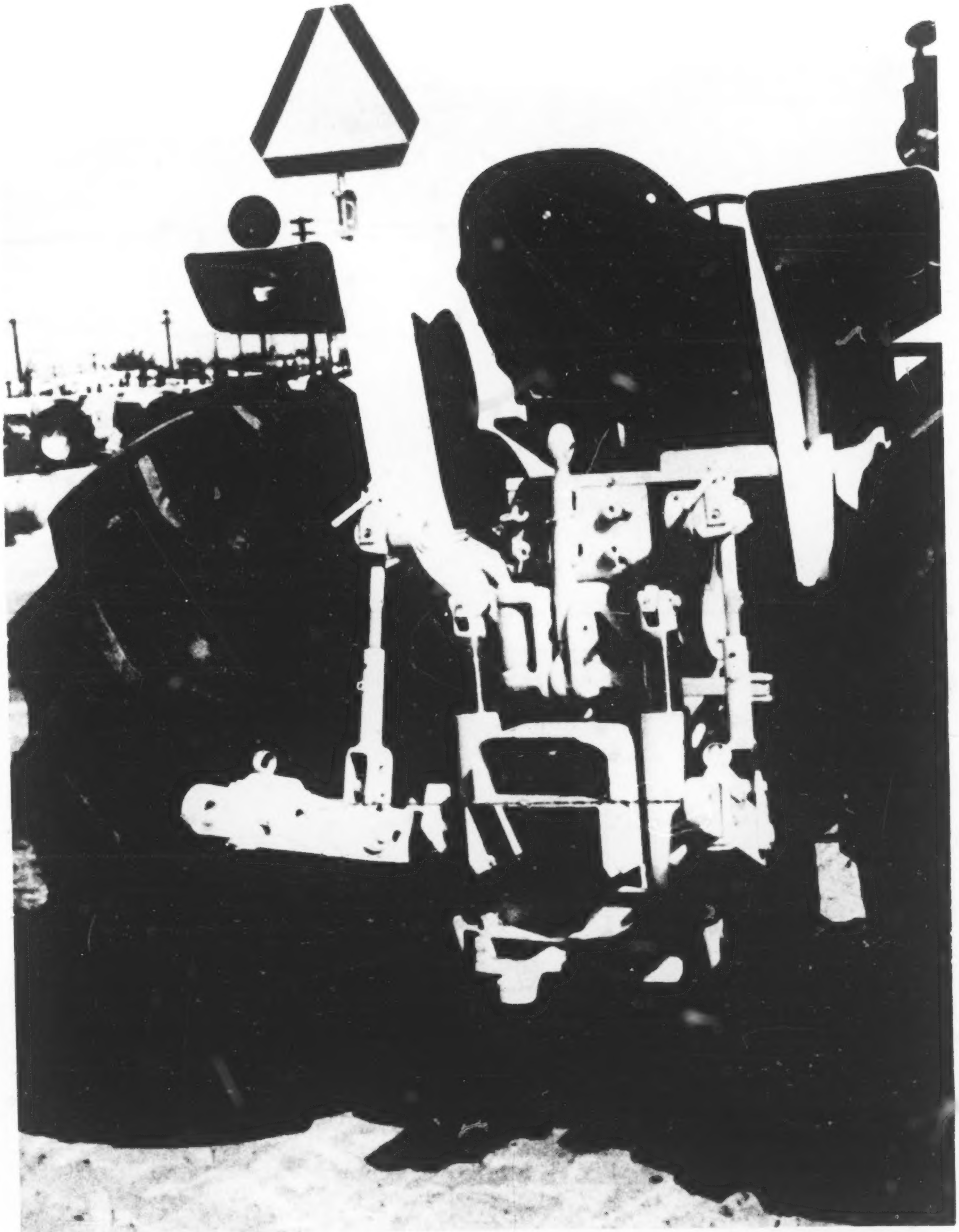


Figure 10. Three-point hitch

embankment. In such cases, training will certainly reduce the probability that an overturn will develop. Once the laws of physics commence to operate, the chances of an unfortunate fatal accident are great.

B. Rollbars and Cabs

(1) Availability of Marketed Countermeasures. Every major tractor manufacturer for a number of years has offered protective roll bars to any interested purchaser. Customer acceptance of such equipment has described the normally slow initial start with approximately 20 percent of production vehicles currently being shipped with some type of rollover protection (Appendix A:A97). The increased use of such equipment is part of an overall upward trend in cab purchases that has been progressing for a number of years and which has been predicted to reach the 50 percent point by 1975 (177:1). This trend is likely to continue since American farmers in buying new tractors are said to seek primarily the advantages gained from increased horsepower (141:20). Increased horsepower along with size allows for more comfort and safety features to be provided at a smaller percentage of the overall tractor cost.

(2) Effectiveness. There are no known operator fatalities occurring with protective frames which meet ASAE and SAE standards. (Appendix A:A97) Production cabs at times exceed ASAE Standard S306. 2. This has prompted some to question the adequacy of the Standard, (Appendix B:B53), a point on which there is disagreement on the part of industry (Appendix B:B60). Present ASAE and SAE standards in this area were developed because the protective frame design criteria used in other countries such as Sweden were considered inadequate for the larger and more powerful machines used on U. S. farms.

Field visits to industry by NHSB personnel indicate that every major tractor manufacturer has a research program documented with movies and/or still photographs (as in Figure 11) to indicate that his protective frames have been designed as a result of actual overturn tests. A common complaint is that it is difficult to get currently-produced vehicles to actually overturn during tests. Tractors with three-point wheel suspension are easier to overturn than others. Newer models with dual rear wheels, three-point hitches, and the like reportedly are subjected to the test a number of times before the vehicle overturns. Vehicles tend to slide down an embankment rather than execute the desired test maneuver, or to come to rest (during a rearward overturn) on the rear hitch mechanism.

There are indications from tractor manufacturer representatives that some of the impetus for the development of roll protective frames and other tractor safety devices has come in response to a little publicized aspect of the tractor manufacturing business, namely, the threat of personal litigation based on product liability suits. This

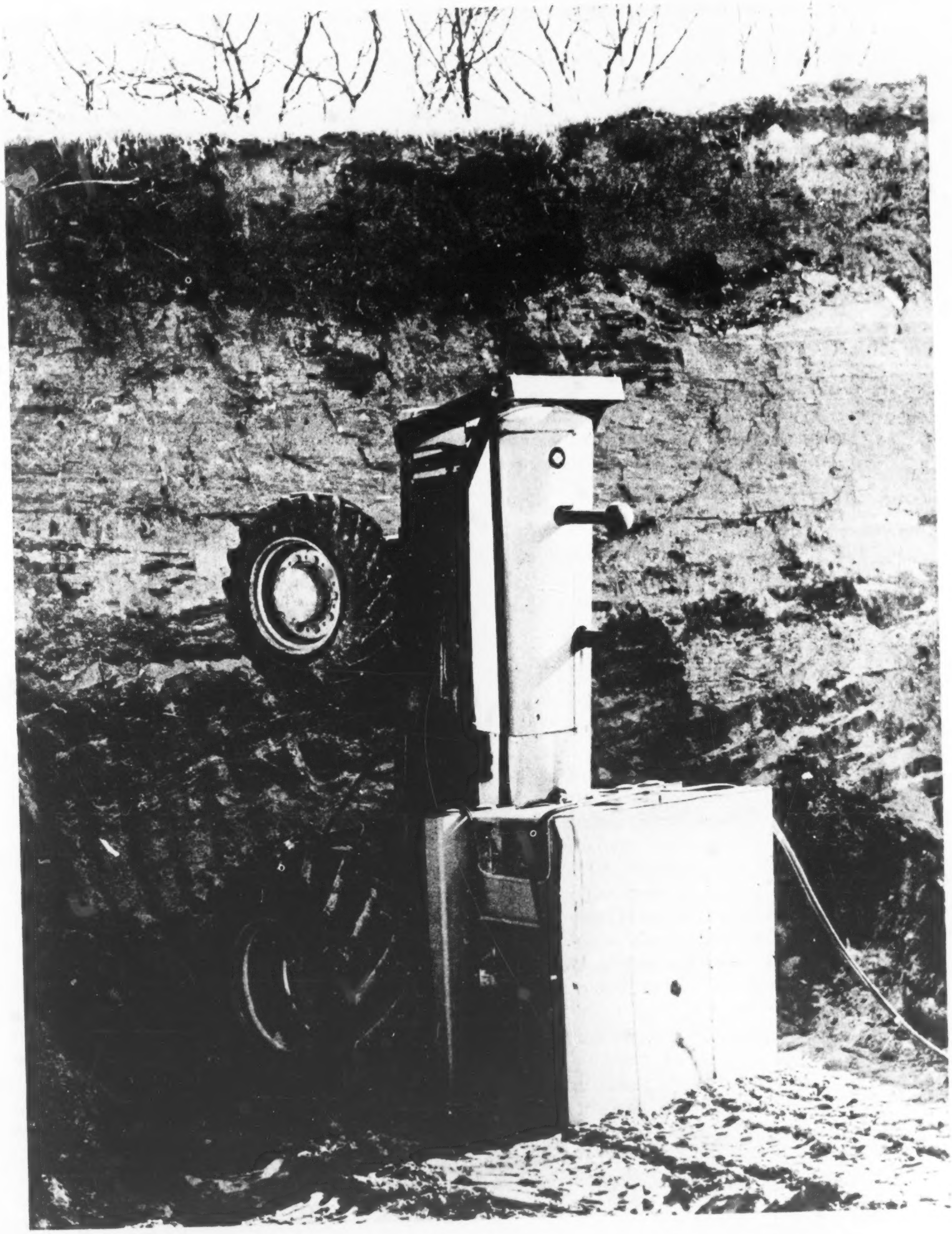


Figure 11. Tractor in rearward overturn with protective cab

factor appears to have played a prominent role in the development of safety equipment in the United States because the fact that such a possibility exists serves as a powerful motivating force on design safety programs. Indoctrination materials for tractor dealers often spell out the advantages in liability which accrue from a good safety program (see Figure 12).

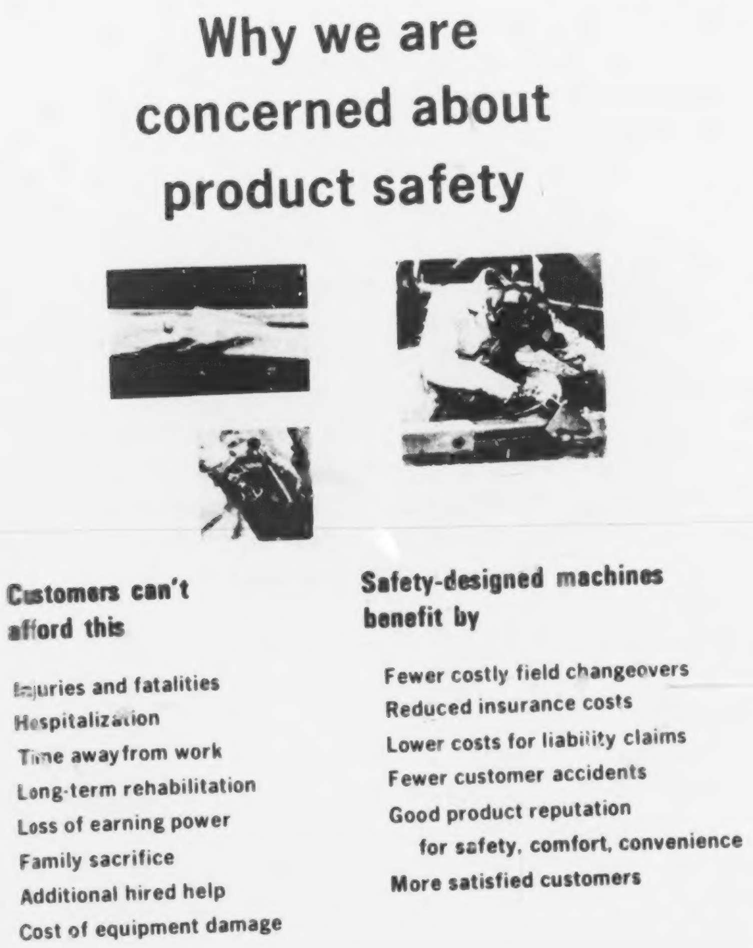
The "inviolable space" approach to overturn protection is used in Sweden, and although it has been successful in reducing the number of overturn fatalities in that country, it requires only a pendulum test; i. e., no actual overturn demonstration is required. Protective frames designed on the basis of such criteria may not protect the operator adequately during certain actual upsets (143:6). The Swedish experience of significantly reduced fatalities due to overturn has been achieved without the requirement for seatbelts; i. e., the operator simply "holds on" in an upset. No American manufacturer, on the other hand, today sells an overturn protective device without a seatbelt, again because of the possibility of litigation arising from an operator being crushed by the safety frame itself while attempting to leap off the machine during an upset.

(3) Cost and Salability. List cost of protective frames range from $195 to $450 depending upon size of the tractor, inclusion of a sunshade or other optional equipment. Cab prices range between 10 and 15 percent of the cost of the vehicle. While cost of a cab for the most popular horsepower tractor sold in the United States is around $1,200 to $1,400, one manufacturer reports twice the rate of acceptance of overturn protective cabs in comparison with the rest of the industry. While safety is mentioned in the promotion of sales, primary features stressed are noise and vibration reduction and the comfort of the operator.

Some of the larger manufacturers market cabs which are not overturn protected under the reasoning that if they do not, "will-fits" (companies marketing equipment that will fit any make of vehicle) will simply supply add-on cabs after purchase.

One tractor manufacturer is attempting to market the protective cab concept with an "environmental kit" which the operator purchases and puts together himself (Figure 13). The operator station is protected by the overturn frame. However, from some customer's point of view, the device is no more than a means to hold a sunshade and a frame for attaching the canvas weather shield.

In conclusion, the general belief of industry representatives appears to be that overturn protected cabs will sell primarily on the basis of comfort and convenience factors, and will eventually become accepted as a necessary item of tractor hardware. Two sources contacted during the course of the study indicated that the shortage of farm labor will commence to show its effect on cab purchases in the



Why we are concerned about product safety

Customers can't afford this

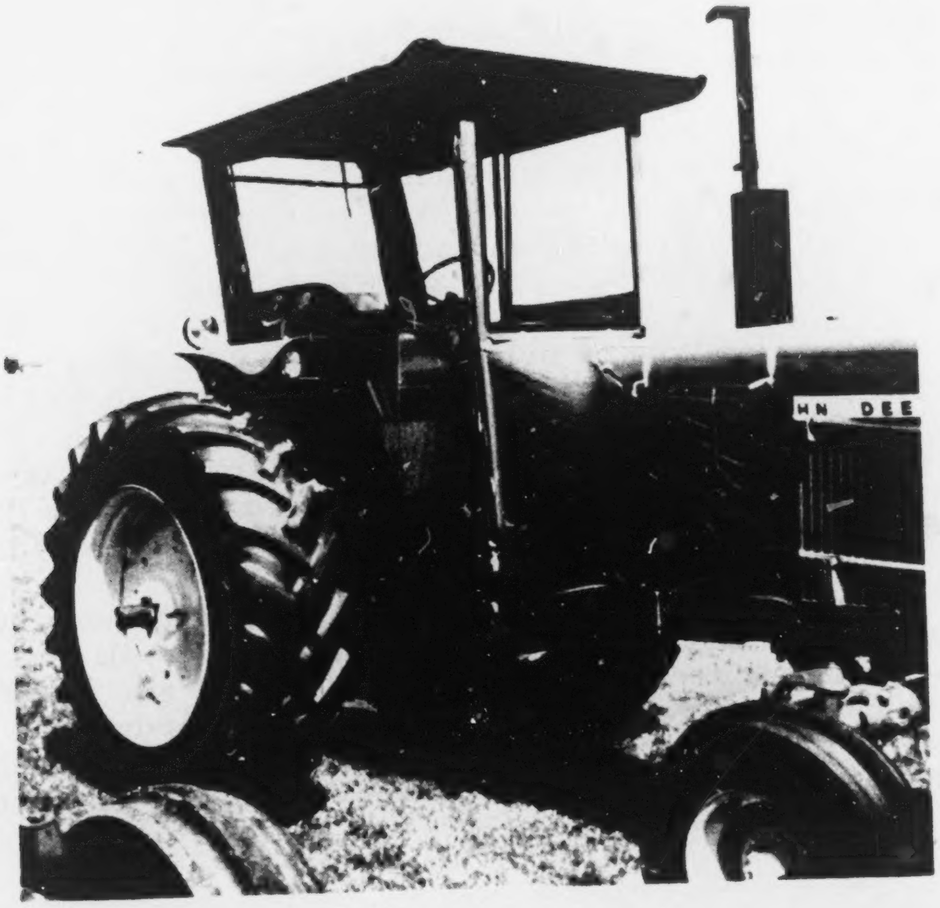
- Injuries and fatalities
- Hospitalization
- Time away from work
- Long-term rehabilitation
- Loss of earning power
- Family sacrifice
- Additional hired help
- Cost of equipment damage

Safety-designed machines benefit by

- Fewer costly field changeovers
- Reduced insurance costs
- Lower costs for liability claims
- Fewer customer accidents
- Good product reputation for safety, comfort, convenience
- More satisfied customers

Figure 12.
Indoctrination materials for tractor dealers.

Figure 13.
Tractor with "environmental kit" protective cab.



near future. Workers are beginning to ask if the owner's vehicle has a comfort cab installed before they will agree to hire on as a tractor operator.

(4) Retrofit.

Most tractors sold on the market today are the same basic models which have been available for a number of years. Therefore, rollbars designed for production tractors in the last few years will also fit tractors sold in earlier years. A survey of the situation has revealed that rollbars are available today which can be placed on most tractors manufactured after 1963. Retrofit of many tractors manufactured before 1964 could be costly due to the reengineering and manufacturing required not only to adapt present-day rollbars but also for the strengthening the final drive housings which may be necessary in order to make them strong enough to support the rollbar in an overturn.

Properly designed rollbars are an effective countermeasure against the overturn fatality. However, the individual farmer is cautioned not to try to modify his tractor, particularly an older tractor, with rollbars himself. There is a degree of engineering skill required to make rollbars which have the proper amount of yield during impact and do not cause the axle housing to break. Homemade rollbars can be dangerous to the operator and damaging to the tractor.

(5) Role of the Federal Government.

The industry was questioned on the possibility of voluntary agreement within the industry to sell only overturn protective vehicles for a certain period of time. The answers reveal that manufacturers cannot voluntarily agree among themselves to provide safety frames on every tractor offered for sale without inviting antitrust investigation for collusion. Whether real or imagined, the fear appears to be that such agreement could be interpreted as price-fixing, or as constituting a move to force smaller, less well-prepared manufacturers out of business.

Manufacturers were also queried on the desirability of a Federal Safety Standard requiring overturn protective devices on tractors except where it would interfere with the normal function of the tractor such as in orchards. Industry appears reluctant to endorse any governmental edict requiring such equipment, even though they developed the devices on their own resources and stood to make a profit on the requirement. Their reasoning, as near as could be determined, is that the farmer is certain to oppose such rulemaking action, and manufacturers thus would not want to be on record as endorsing such specification.

Hansen expresses such a view on the subject in the FIEI paper prepared for this report:

> "Forcing the sale of safety features on unwilling buyers has, in the past and continues to be, a waste of economic wealth of this nation. If the user is not convinced from his own experience and judgment that the safety device is necessary, he will not maintain and use it even though he may be required to buy it. In such cases, there are insufficient law enforcement officers in this nation to enforce the use of such safety features, since their use is primarily on the farmers' private property." (Appendix A:A100).

Hodges points out that voluntary action on safety matters appears to be relatively advanced in the farm machinery field. (Appendix A:A130). A plan currently under development by the ASAE is designed to reduce agricultural fatalities by 50 percent over the next ten years (Appendix B:B115). This plan includes the cooperation of the best known agricultural safety experts in the country, representing inputs from government, industry and the university.

3.2 Power Takeoff (PTO) Accidents.

A search of available literature on PTO accidents has shown Knapp to have made perhaps the most complete study of this accident type. Because of this, his work is referenced extensively in this section of the report. Also, frequent reference is made to a paper on power drive shafts by Bornzin.

3.2.1 Description of the Power Takeoff Mechanism

Knapp states:

> "The power takeoff mechanism [Figure 14] is a rotating shaft attached to the tractor at one end and the machine to be driven at the other. There is a coupling device for attaching at either end and two or more universal joints which permit the equipment (tractor and attached machine) to turn corners. These universal joints also allow for angular displacement (not straight line) drives. The PTO may, because of the kinds of machines to which it is to be attached, transmit energy varying from fractions of a horsepower to many, depending upon the rating of the tractor engine which is the power source.
>
> "The PTO is attached to the tractor by means of a spline collar that slides over the spline

shaft protruding from the tractor differential (rear of tractor). This collar is usually held in place by a spring-loaded pin which protrudes from the side of the PTO proper and latches into a recessed area on the tractor spline. The end of the PTO shaft, which drives the machine, may have a variety of attachment principles from a spline and spring-loaded attachment like that on the tractor end, to a round shaft with bolt and key mechanism, to a bolted square shaft. Grease fittings protrude from the side of some of the PTO shafts." (72:2).

3.2.2 How PTO Accidents Occur

Knapp states:

> "Essentially, every PTO accident involves the entangling of the victim's clothing by the rapidly revolving shaft. The speed of rotation of the shaft precludes escape and the power transmitted is so great that there is usually little possibility of engine stall. Possible sequels are the following:
>
> 1. The clothing yields, freeing the man without injury.
>
> 2. The clothing yields with minimal trauma, such as friction burns, scrapes, sprains, and bruises.
>
> 3. The clothing yields and removes loose skin in the scrotal region.
>
> 4. The clothing yields following wedging of the victim's body in or against the machine with severe trauma such as lacerations, broken bones, dismemberment of the extremities, or strangulation.
>
> 5. The clothing does not yield and the body of the victim is rotated around the shaft with extensive mutilation and early death." (72:8).

There is also a small number of PTO accidents that occur when the telescoping portion of the PTO is extended too far allowing the shaft to come apart, swing free, to hit the operator, and, of course, there are mechanical failures such as bolt failures which can cause accidents.

The usual place for clothes to become entangled in the PTO is a protrusion such as the pin connecting the PTO to the tractor and to the implement.

3.2.3 PTO Design

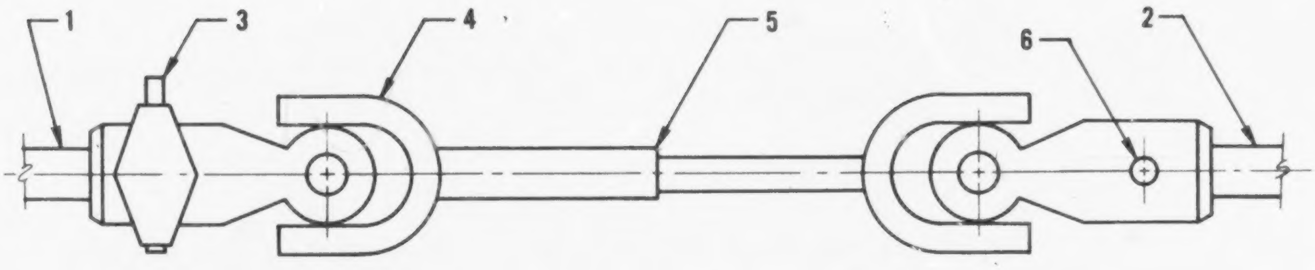
The design problems in making a PTO are formidable. Bornzin states: ". . . power to be transmitted had to go through a drive line which was capable of any gyration imaginable. It had to take power around corners at angles up to 90°. It had to be capable of permitting the machine to follow ground undulations -- it had to shrink in length when tractor and implement came closer together and had to expand in length as the machines separated, all this while transmitting the power of the tractor to the implement. This has been accomplished through the use of a telescoping universal joint shaft . . . ."(Appendix A:A109). It should be noted here that the problem has not been completely solved with the telescoping shaft, for some implements such a forage wagon are required to have the PTO shaft disconnected while the tractor is traveling.

3.2.4 Protection Provided by Tractor Manufacturers

Manufacturers of tractors provide a master shield with power takeoff as shown in Figure 15. This shield, covered by SAE standards S718c and S719c (ASAE standards S203.7 and S204.6) Knapp says is ". . . mounted in such a manner as to protect the exposed spline ends of the PTO shaft when using the integral mounted shield, and serve as mounting points for the inverted trough shield." (72:6&7).

There are apparently two different design concepts regarding the attachment of the master shield. One concept is to design a shield that can be easily removed and attached so that the operator can remove the shield when attaching PTO shaft, and reattach the shield once the appropriate shaft is in place. The other is to make the shield more difficult to remove, and, if the farmer does not remove it, then he will not forget to put it back. Both concepts have deficiencies. The easily removed shield actually is left off of machines in the field. The hard-to-remove shield is also left off in the field, because there are some attachments such as pumps which require its removal. Once the shield is removed, in many cases, it does not get back on.

Power takeoff shielding for PTO shafting is normally furnished by the implement manufacturers since it is they who normally provide the PTO shafting. Two types of shielding normally are furnished. The



(1) TRACTOR PTO SHAFT

(2) DRIVEN IMPLEMENT SHAFT

(3) SPRING-LOADED PIN CONNECTING PTO TO TRACTOR

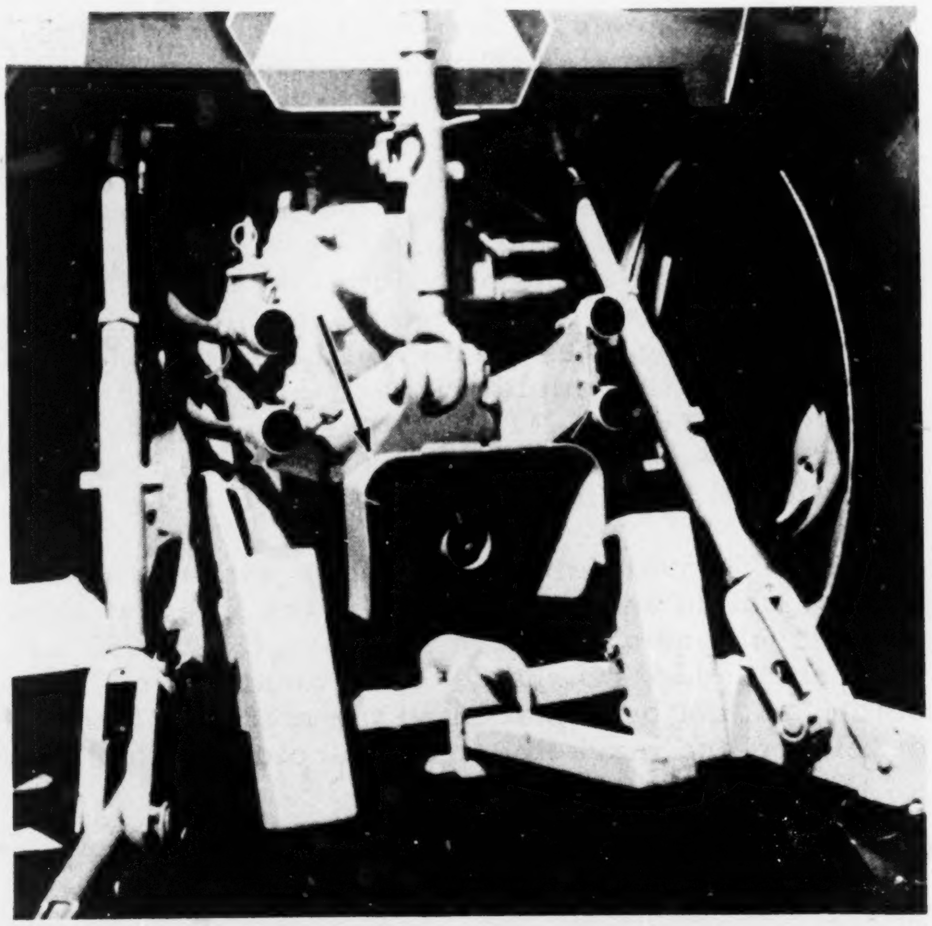
(4) UNIVERSAL JOINT

(5) TELESCOPING PORTION OF PTO SHAFT

(6) PIN AND KD KEYWAY FOR CONNECTING PTO TO IMPLEMENT

Figure 14. Power takeoff mechanism

Figure 15.
PTO master shield



first, popular in the 1940's and the 1950's, is the inverted trough or U-shaped shielding device. The second is the integral mounting shield which has been the popular type in the 1960's.

A. Inverted U-Shaped Shielding Device

This type, illustrated in Figure 16, is an inverted U-shaped, extendable shield with support at either end. The PTO shaft assembly revolves underneath the shield and protection is offered the worker from side or top contact. This type shield in new condition apparently gives acceptable protection to the worker. However, the shield is susceptible to being bent and damaged and, when damaged, is left off of the machine. Also, if the tractor master shield is not in place, there is no place to attach the shaft shield and, therefore, it is not put in place. In some cases, the shield was made according to Bornzin". . . an integral part of the implement by fastening it with a rivet or other more permanent means, thereby making it difficult to remove and, although many users complained because serviceability often was more difficult, it did contribute towards the availability of the shield when coupling the implement to the tractor." (Appendix A:A110).

B. Integral Shield

The integral shield is a rotatable bell end shield which is journaled on the drive line and free to rotate independant of the drive line. The integral shield (Figure 17) solved two problems inherent in the design of the inverted U-shaped shield, that is, its easy removability characteristic and the lack of protection from the bottom. However there still remains the problem of the space between the end bell of the integral shield and the master shield. As Knapp points out, this space is such ". . . as to permit the jamming of an upper or lower extremity of the body into this clearance area accidentally and is nearly always wide enough to permit the movement of loose clothing into the opening where it can become entangled." (72:7&8). This clearance between the shields is necessary because "Considerable angular displacement of the PTO with the line of travel is often required during operation, especially if the machinery is moving about as well as in operation at the time." (72:7).

To overcome the problem with the space between the tractor master shield and the end bell of the integral shield, the SAE and ASAE have developed a tentative standard (SAE J955 and ASAE 5297T) for a fully enclosed PTO shaft. Unfortunately, a PTO shaft with this type shield has not been placed on the market. Once the shield is fully developed and marketed, PTO accidents should be greatly reduced.

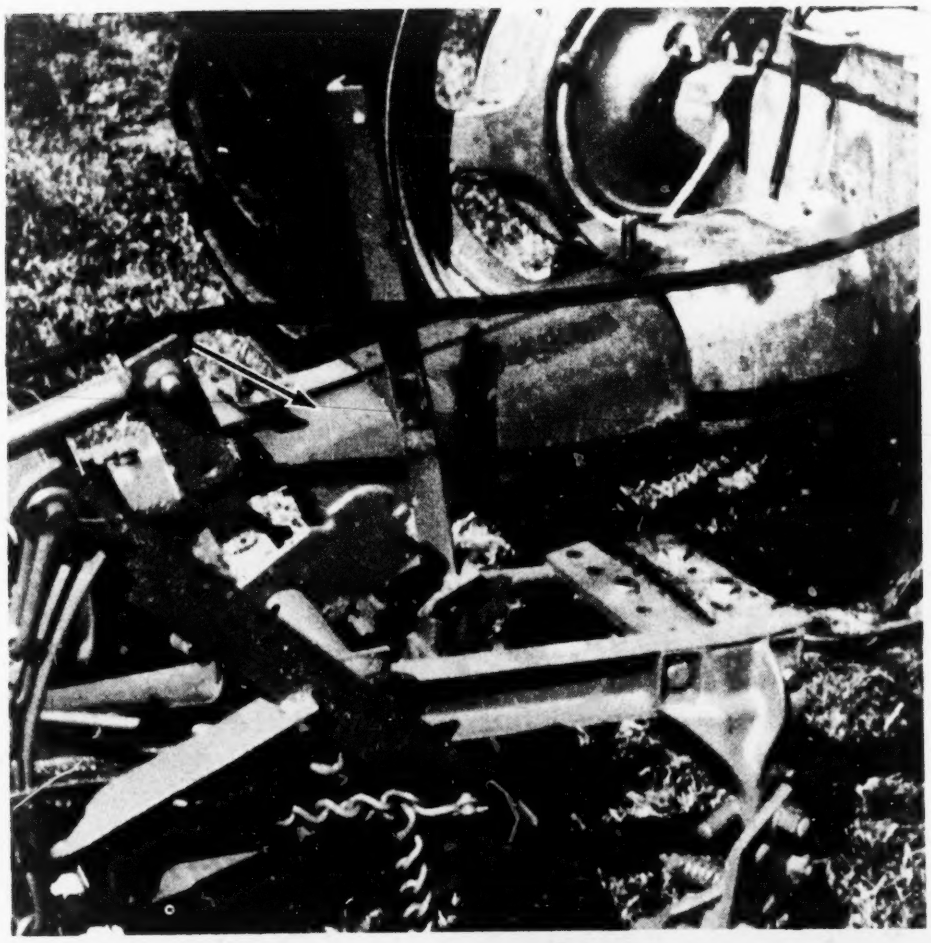
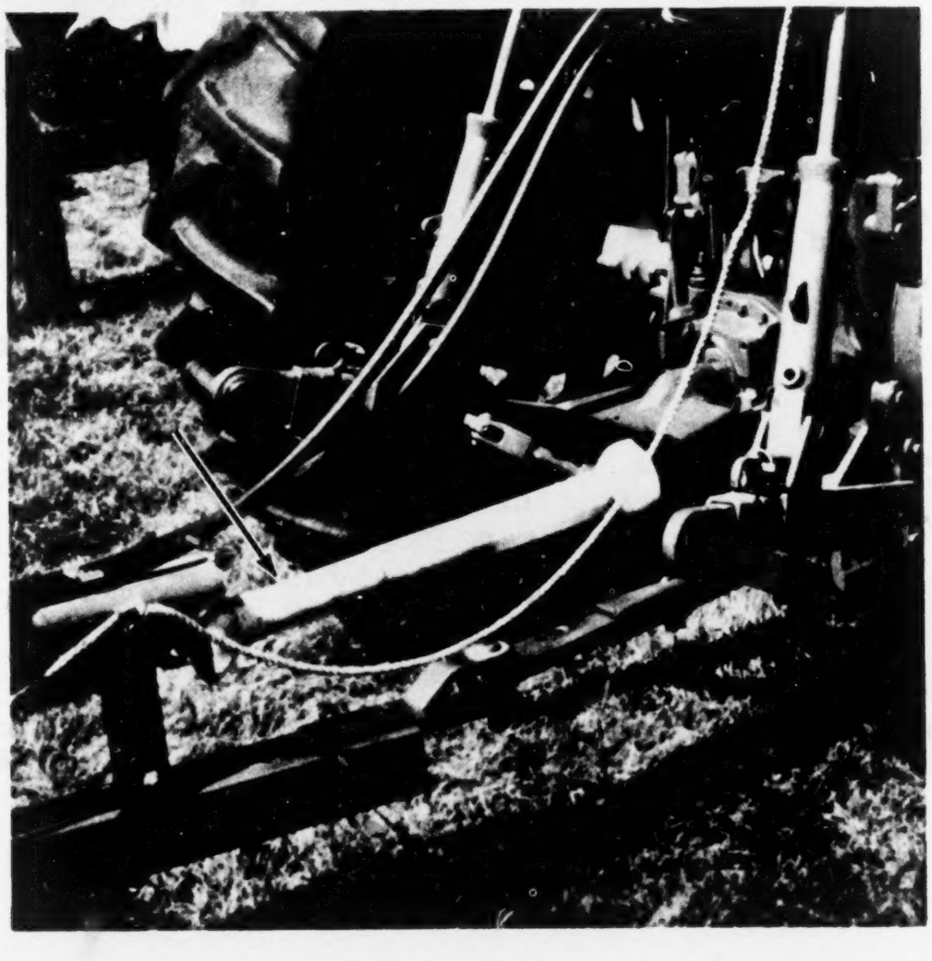


Figure 16.
PTO inverted U-shaped shield

Figure 17.
PTO integral shield



3.2.5 Other Tractor Design Features Contributing to PTO Accidents

In 1940, most of the tractors had operator's seats which were located above and behind the center line of the rear axle. This design feature made it easier to get on and off the tractor from the rear by stepping on the drawbar, and it was also easy to step up on the drawbar and manipulate controls on the tractor. Accident reports show standing on the drawbar to be the most common way of getting caught by the PTO shaft. The late model tractors are made so mounting and dismounting of the tractor is done in front of the wheels, also the controls are difficult to reach from the rear (especially when a cab is mounted on the tractor). This design change should have an affect on reducing the number of PTO accidents occurring with new tractors.

To a degree, mechanical failures of the PTO are prevented when manufactured to conform to SAE Standards J718 and J719 (ASAE Standards S703.6 and S204.5). They specify many dimensional limitations to prevent overloading of the drive lines and a requirement for a means to prevent the operator from operating the PTO at a speed greater than that specified by the standard. In addition, as pointed out by Bornzin, SAE Standard J721 (ASAE Standard R207.7) specifies ". . . maximum bending and torsional load limitations permissable for transmittal and, if necessary, overload protective devices are to be provided by the manufacturer when it is possible to exceed the specified maximum loads." (Appendix A:A115).

3.2.6 Other Accidents to Which PTO Design Contributes

Bornzin has these comments regarding PTO design and accidents:

> "For many years operators of farm machinery have been warned to stop the tractor engine before performing duties off the tractor, such as unplugging the feed mechanism of a machine. It is when this warning is ignored that a hazard exists. One measure, which can be taken to minimize the possibilities of an accident from this cause, is to prevent the machine from plugging in the first place. The operator can control this by not crowding the crop into the machine. The individual manufacturers have taken steps to aid in the prevention of plugging by the following:
>
> "The operation of the power take-off shaft of earlier tractors was directly related to the tractor master clutch, which also controlled ground travel. When the tractor was moving forward into

the crop with the PTO shaft engaged and the implement feed mechanism became overloaded by the crop, it was necessary for the operator to perform the following acts to release the overcrowding:

1. Depress or release the master clutch which stopped forward travel and rotation of the PTO.
2. Shift the tractor propulsion transmission into neutral.
3. Re-engage the master clutch which now operated the PTO only, thereby relieving the overcrowded condition of the implement feed mechanism.
4. Again depress or release the master clutch.
5. Shift the tractor propulsion transmission back into gear.
6. Engage the master clutch and proceed with normal operation.

"It can readily be seen that rather than go through this procedure the operator might gamble on not plugging the machine when it became overcrowded and often he would lose the gamble which would require him to dismount from the tractor to unplug the machine. He might even choose to allow the PTO shaft to continue to run so that the machine could remove the excess crop as he unplugged the feeder. This procedure presented hazardous conditions in areas other than just the PTO.

"The first provision to alleviate this condition was the introduction of individual control of ground travel and PTO operation. By being able to stop the forward travel of the tractor and implement, but allowing the PTO to continue to operate, the overloaded condition of the implement could be relieved without completely plugging the mechanism.

"Next came the introduction of a rapid means to change ground speed. This allowed the operator to immediately change his forward travel to a slower stepped range by pushing a lever and in so doing he could regulate the amount of material entering the feed mechanism of the implement.

> "The latest evolution in tractor propulsion is the hydrostatic transmission which permits the operator to control his forward ground travel at an infinitely variable speed ranging from zero miles per hour to the top speed of the tractor; meanwhile his PTO is operating at the fixed proper speed. The speed control of the hydrostatic transmission is a simple easy-to-operate lever which increases the ground speed of the tractor as the lever is advanced forward and reverses the tractor direction when pulled rearward from a neutral position. With this totally variable ground speed control, there is little or no reason for the operator to overcrowd or plug his implement." (Appendix A:A116).

3.2.7 Concluding Statement

PTO associated accidents should occur less frequently on newer tractors which have to be mounted in front of the wheels. Also, PTO accidents are believed to be less frequent on tractors equipped with the integral mounted shield. When the fully enclosed integral mounted shield is completely developed and marketed, PTO accidents on equipment utilizing this shield should be minimal.

3.3 Health Hazards

In addition to the acute effects of tractor crashes, there are numerous more subtle effects associated with the sustained operation of a tractor. These develop as the result of the temperature in which the operator works; the dust and spray particles he breathes; the toxic fumes he inhales; the noise and vibration levels to which he is subjected; and other environmentally induced injuries. If the length and intensity of the exposure to these phenomena is sufficient, they can lead to permanent physical damage as well as to temporary inability to perform optimally. Unlike the effects of a tractor crash, the health effects of tractor associated operations are gradual and cumulative and thus sometimes result in conditions that are far advanced before they are detected and treatment is begun. Donaldson (23:27) provides an excellent review of the physiological effects of physical and mechanical constraints of the machine, health effects due to exposure during operation, temperature effects, and the impact of noise. Despite the presence of so many conditions that can affect the health of the operator adversely, there have been surprisingly few studies which have focused on these conditions. Some of the new tractor cab designs eliminate or reduce the injurious effects of some of these hazards to health; e. g., extremes of temperature and exposure to sun rays, noise and vibration levels, breathing of dusts and sprays, and inhalation of toxic fumes. However, the bulk of the tractor operator population is and will continue to be exposed to these and other hazards for some time. Thus, there is a requirement to intensify the search for ways to attenuate the effects of these hazards to health. Some of the effects are reported on below.

3. 3. 1 Physical Effects

More than 20 years ago, Paulson (117) observed that driving a farm tractor produced distressing symptoms, the most common being lower backache or "tractor back". He reported the gamut of complaints to range through neck stiffness and extremity pain, to digestive upsets, frequent stools, heartburn, urinary frequency, and dizziness. The complaints occurred primarily during the seasons of "heavy" tractor work, like plowing and discing, and when the ground was hard and rough. In a study reported some ten years ago, the Roseggers (129) examined 371 tractor drivers in Europe to assess whether the vibrations and shocks associated with tractor operation caused damage to health. As a result of their investigation, they reported that the human body tries to counteract vibrations by a constant contraction and relaxation of the muscular system. Over a prolonged period, this causes changes in the response of the autonomic nervous system which, in turn, affects the tone of the involuntary muscle system of the gastrointestinal tract, resulting in interference with normal digestion. These findings support Paulson's earlier observations. In a survey designed to examine the relationship between disorders of the spine and supporting structures and the driving of trucks and tractors, Fishbein and Salter (35), some 20 years ago, polled 1,474 orthopaedic surgeons in the United States. The investigators reported that the survey results definitely established that regular seating on trucks and tractors either caused or aggravated a number of disorders of the spine and supporting structure of the driver. A total of 7, 851 cases was reported in which 45 different disorders were named.

While considerable work has been done to improve seating and to reduce vibration for the tractor operator since Fishbein and Salter's report (53, 54, 153, 160, 162, 163) the health hazards of driving tractors constitute a medical problem which has not recently received the attention or study it deserves, either by the medical profession or the equipment manufacturers.

3. 3. 2 Noise

Audiograms of farmers who drive tractors indicate that tractor noise may be the principal factor in high frequency hearing loss among tractor operators. (84:2). Research at the University of Nebraska determined that the sound pressure levels for tractors varied between 97 decibels (db) and 114 db as compared with the normally accepted level of 85 db as the upper limit of sound pressure to which a person may be exposed over an extended period of time without appreciable hearing loss. (84:3). For continuous, steady noises, the limits of the Walsh-Healy Act are shown in Table 10.

TABLE 10
PERMISSIBLE NOISE EXPOSURES

Duration per day, hr	Sound level, dB(A)
8	90
6	92
4	95
3	97
2	100
1 1/2	102
1	105
3/4	107
1/2	110
1/4	115 max.

Donaldson, in discussing noise-induced hearing loss, states:

> "At first, attention was focused on the discomfort and irritant effects of noise. Farmers operating powerful machines may be initially more concerned with the annoyance factor of noise than with the gradual physical damage to hearing. Probably, they correctly recognize noise as being distracting and fatiguing. In this sense noise may have serious effects in diverting attention . . . and this may lead to an increased risk of accidents due to inattention to controls.
>
> "Much of the more recent work on noise has been on physiological effects and noise-induced hearing loss. Despite the volume of work in this area . . . there is some conflict in the ideas and information presented in the published work. It is clear, however, that farm machine operators are being exposed to noise levels that are likely to cause future hearing loss, but the amount of disability and the number of farmers affected are not established." (23:32).

Schnieder reports that in about 1967, added interest was placed on the noise levels of tractors. However, he cautions "Much more time, money and energy will be spent before the problem is completely solved but the tractor design engineers recognize the problem and are attempting to alleviate it." (Appendix A:A11).Effective in 1970, noise level testing became a part of the Nebraska Tractor Test Code.

Hodges discusses the increased interest of government, industry and standards organizations in the possible effects from overexposure to excessive noise levels. (Appendix A:A129).

Efforts to initiate a hearing conservation program have been noted in some States. For example, the Speech and Hearing Clinic at the University of Nebraska has administered hearing tests to large numbers of that State's farm population. And, 4-H and other farm-oriented groups are sponsoring the sale of ear protection, reportedly with considerable success.

3. 3. 3 Other Exposure Effects

Most tractor operators, except those whose tractors are equipped with enclosed cabs, are exposed to weather, to the dust, noise, heat and fumes produced by the tractor, and to chemical agents in the form of sprays and other particulate matter when using the tractor during spraying operations and when spreading fertilizer. Some of the chemical agents used are extremely toxic; e.g., parathion. Schnieder has these observations regarding exposure effects of tractor operation:

> "Exhaust vapors also have an important place in future design. With our added emphasis on air pollution, it is increasingly necessary that exhaust emissions be as free of toxic products as possible.
>
> "We must envision the day when machine operators can work in an environment free of dust, pollen and dangerous chemicals. With this need comes the demand for a filtration system that will work satisfactorily with a broad band of materials.
>
> "We must also envision the operator working in an environment of controlled temperature and humidity. The surroundings should be equal to those that he would find in his own home or automobile. Actually, many farmers spend more time on their tractors than they do in their automobile. It's time they demand the same comfort. We must also envision a remote controlled system for extremely hazardous jobs and somewhere in the future this type of machine for most farm operations. . . . "(Appendix A:A26).

3. 3. 4 Concluding Statement

There are health hazards of a medical nature associated with operating agricultural tractors. And, while the industry has made impressive strides to eliminate or attenuate these hazards, much remains to be done. A simple example is the tractor cab which should be designed to provide a toxic-free atmosphere during operation as well as a roll protective environment. Wardle (Appendix A:A41) provides some interesting observations in this regard.

Schnieder sees a significant role for human factors engineering in correcting or compensating for many of the exposure effects of tractor operation. He cites these illustrations:

> ". . . noise level is one good example. Attempts are being made to produce quiet equipment. This covers a multitude of noise making systems since the transmission, the engine exhaust, engine clatter, fan noise, turbo-charger noise, all have to be considered. We are also attempting to improve the environment in which the operator works. With a crush resistant cab he has the protection of the cab. With the filter system we can filter dust, pollens and mold spores out of the air that he breathes. With an air conditioning unit the operator can work in comfort during the summer. With a heater he can work in warm surroundings during the winter. The operator is also protected from the rays of the sun, cutting down on the incidence of lip cancer. Those who are affected by allergies such as pollen, by bee or insect stings are also able to work in the comfort of a protective cab. The operator is also protected from hydraulic hose breakage, from anhydrous hose breakage, or from flying material which might break from equipment as it is being put under heavy stress. Seats are being improved for operator comfort. Controls are placed at fingertip length. Steering wheels are being made so that they may be adjusted to the size of the operator. Power steering reduces the amount of energy a man must exert. Tinted glass can cut down on the amount of sun rays that the individual receives. These are just a few of the benefits of design that are occurring at this time. Some of the plans for the future are quite intriguing. . . ." (Appendix A:A20).

3. 4 General Design Features

In this section, the following are discussed: human engineering factors, maintenance hazards, and tractor design in general. Several factors that are associated with tractor accidents other than overturns and PTO types are discussed, along with suggestions for their correction or attenuation.

3. 4. 1 Human Engineering Factors

While numerous improvements have been made over the past 10 years, certainly more can be done which would increase the margin of safety for the operator. The material below is based on a brief survey of human engineering practices in the industry made during preparatory phases of this report. Present and possible future improvements which could add to the safety, ease, and productivity of farm tractor operation are discussed.

A. Present Improvements. Certain unsafe characteristics which were once an accepted part of farm tractor design are now obsolete as technological advances and productivity factors allow features to be added. Certain of these features are as follows:

(1) Self-Equalizing Brakes. Individual rear wheel brakes must be provided to aid in steering since a tremendous force develops rearward to hold the vehicle in a straight line when a heavy tillage implement is being pulled. Older systems allowed differentiated wear on the brake shoes due to continued use of one brake, and even when the mechanical lock between the pedals was used as recommended, road speeds still produced an overturn hazard because the unequal wear allowed one brake to be applied before the other.

Full hydraulic systems are now standard on all tractors thereby reducing this hazard by equalizing the pressure to each wheel when both pedals are depressed.

(2) Vibration-Free Mirrors. Tractor vibration in the past precluded the use of rearview mirrors. Newer systems now isolate the entire operator station (including rollbar) on rubber mounts. Mirrors were demonstrated during visits by NHSB personnel which did not vibrate at road speeds even on pavement where harmonics of tread frequencies provide significant inputs.

It should be noted that self-leveling hitches and self-tripping plows reduce the necessity for continuously peering backward while operating the vehicle on the farm.

(3) Acoustic and Vibratory Isolation. Exhaust stacks on newer vehicles now have an effective muffler and have been extended to exceed the height of the cab or the sunshade on the rollframe. The result is that exhaust noise and fumes are kept away from the operator's station. The ability to do so, however, is limited by the requirement to pass through barn doors, and to keep the vent away from loose hay for fire prevention reasons, and preventing the pipe from burning the operator while attaching implements.

A spring suspension system could be developed for the entire mass of the tractor to reduce vibration and soften the ride for the operator though the cost would be prohibitive. Damped and suspended seats have been developed as an alternative, all of which are adjustable with some allowing adjustment of the rate of response to bouncing and vibration.

Associated with the factor of seats is the recurring question of passengers and passenger safety. Manufacturers cannot discourage passengers from riding on farm tractors and at the same time provide seats for those who elect to ignore the warning against such a practice. There is additionally the problem of how to protect such a rider in the event of an overturn. The cost (eventually to the farmer) of providing protected passenger seating, coupled with the possibilities of litigation for not providing the protection have very likely served to keep passenger seats off these working vehicles in much the same manner as trucking firms specify "No Riders". It is perhaps significant that some trucking companies even purchase cabs with only one seat.

(4) Spacious and Human-Engineered Operator Stations. The most popular-sized tractor in the United States falls in the 95-100 horsepower class. Operator stations on these large machines for the most part, appear to be spacious and well-designed from the human factors standpoint (see Figures 18 through 33 below).

B. Possible Future Improvements. A brief introduction to some of the possible advantages deriving from the further application of human engineering expertise to the design of farm equipment is presented below. It is important to note that definite conclusions in this complex area can be reached only after careful study and analysis.

(1) Task Analysis. Task analysis has implications for both systems design (some examples of which are described below), and for the development of tractor operator training programs. Application of task analysis to training programs is discussed in Chapter Four. No formal or systematic task analysis appears to have ever been performed on the tractor operator's job. In contrast to other types of production such as factory operations, only isolated systematic studies have been made of timesaving methods whereby the operator can more quickly, easily, and safely perform a required function. For example, one large company marketed a "quick-hitch" for a number of years which was later replaced by the standard three-point hitch of today. While the latter three-point method has certain technological advantages over the quick-hitch approach, the quick-hitch certainly takes less time, produces fewer bruised knuckles, and removes the necessity for the operator to go between the tractor and implement in order to couple the two together. Tractor "square dances" at State fairs have been used to demonstrate the facility with which the quick method allows the operator to drop one implement and pick up another.

The point to be made is that careful analysis of the movements of the tractor operator would reveal when he is unnecessarily exposing himself to danger and could help develop an improved quick-hitch for the newer three-point system. It should be mentioned that there presently is just such a hitch on the market although it is expensive, heavy, bulky, and believed not likely to gain wide acceptance.

Coupled with the concern for safety is the fact that no company now offers a means for applying brakes on a tractor from the rear where the hitching operation is taking place. If the tractor begins to coast while the operator is hitching onto an implement, he simply must be agile enough to leap out of the way in time to keep from being crushed between the two heavy pieces of equipment.

Ample film footage of tractor operations is available to indicate that the connection of hydraulic hoses could be greatly improved for ease of hookup. The operator typically alights from the left side of the tractor and moves to the rear to connect the three-point hitch mechanism. Following this, he attaches the hydraulic hose if required. In performing the latter, he must often lean over the entire hitching apparatus to push the hoses into the coupling on the upper right rear of the tractor. This awkward movement requires substantial force to be applied, thus adding to the difficulty of hooking onto an implement.

With further regard to attaching implements, it was indicated earlier that there are basically two approaches used in designing PTO guards. One consists of designing guards that are easily removed; the other, designing fixed guards that cannot be removed. A third alternative that should be considered is a guard which swings out of the way when implements are attached, but which swings back or drops into place when released.

Finally, a thorough task analysis would point up a number of monitoring requirements such as the necessity to look to the rear when towing a self-tripping plowshare on rocky ground. Diverting attention from the path ahead increases the likelihood of overturns or other types of accidents. Self-resetting plowshares would reduce the need for looking to the rear when towing self-tripping plowshares on rocky ground, but a better solution might be a feedback device on the tractor instrument panel which indicates the status of the plowshares.

(2) Control Design. Careful human engineering could improve the design of controls, their location, and their operation. Examples of possibilities in this area are discussed below:

(a) The engine speed control requirement in ASAE Recommendation R335 can easily lead to confusion as to which way to move the hand control, depending upon where the control is mounted. Typically, an increase in speed would result from a forward motion of the lever as viewed by the operator from a seated position. However, this is the ASAE recommendation only if the direction of the control's location is on a plane parallel to the longitudinal axis of the vehicle. If the design of the engine speed control is such that the control's motion is on a plane parallel with the rim of the steering wheel, the operator must pull backward or downward on the control to increase engine speed. Such a variation in the placement of the engine speed control can lead to accidents when the operator changes from one tractor model to another.

(b) Smaller tractors are usually used in utility situations where the operator frequently is required to mount or dismount to open and close gates or barn doors. Frequently, a number of tradeoffs have to be made during the design of such vehicles, since space may not be available to design the operator's work station in conformance with commonly accepted human engineering principles. Much of the farm work in other countries is carried out with "utility tractors". An excellent summary of some of the human factors problems encountered in the design and use of such tractors, most of which are manufactured abroad, has been provided by Mr. Geoffrey Mc Donald of the Department of Mechanical Engineering, University of Queensland, in Australia, Figures 34 through 39, taken from Mc Donald's work, illustrate examples of improper design from a human factors standpoint. These examples apply mostly to small utility tractors and do not represent the majority of American-made equipment.

(c) Clutch pedals that operate vertically, examples of which are shown in Figures 34 and 35, present a hazard to the operator. During utility work, he may step on the pedal while placing the gearshift in what he thinks is a neutral position. If the gearshift is not placed in a neutral position, the vehicle may lurch forward as the operator's foot leaves the clutch pedal and while the operator is directly in front of the left rear wheel.

(3) Operator Station Location. Realizing that the location of the operator on farm tractors has not changed appreciably in some 50 years, NHSB observers during field visits were, nevertheless, impressed with the possibility of locating the operator nearer the front and lowermost point on the vehicle. Most controls today are of the servo-boost variety with no requirement for the full steering column as exists in the case of the automobile. Thus, the operator could be located at the very front of the vehicle, at the very rear, or even at the side, depending on the intended use of the tractor. Even on articulated, four-wheel drive tractors, the operator is still placed at the highest point rather than sheltered between, say, one set of driving wheels. While a large number of tradeoffs must be considered in such basic changes in design, it seems reasonable that roll protection would be easier and less costly to effect if the operator's station had a lower profile. Additional study in this area appears to be warranted.

3.4.2 Maintenance Hazards

Battery filler caps have been designed to prevent spillage on the operator in the event of an overturn. Fuel tank filler caps also have been designed similarly, however, on many tractors the fuel tank

Figure 18.
Operator's cab is an integral part of the tractor and provides complete roll protection.

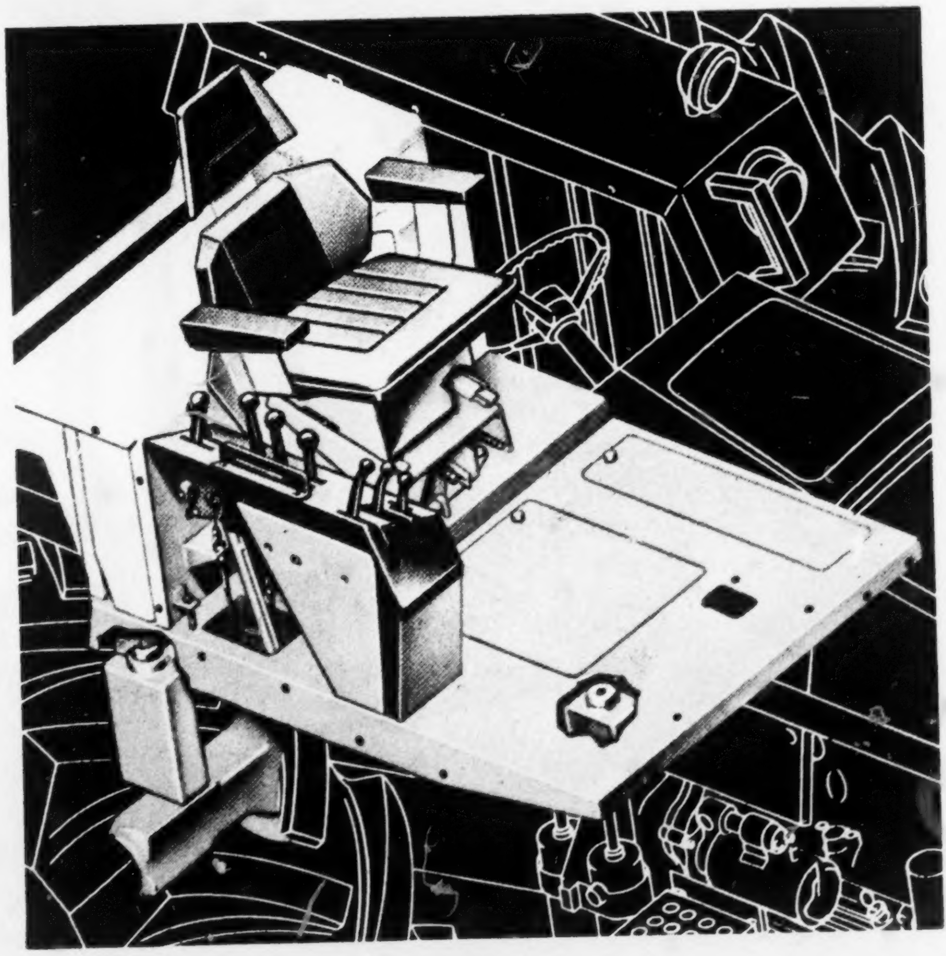


Figure 19.
The platform is isolated from the tractor chassis with rubber cushion mountings.

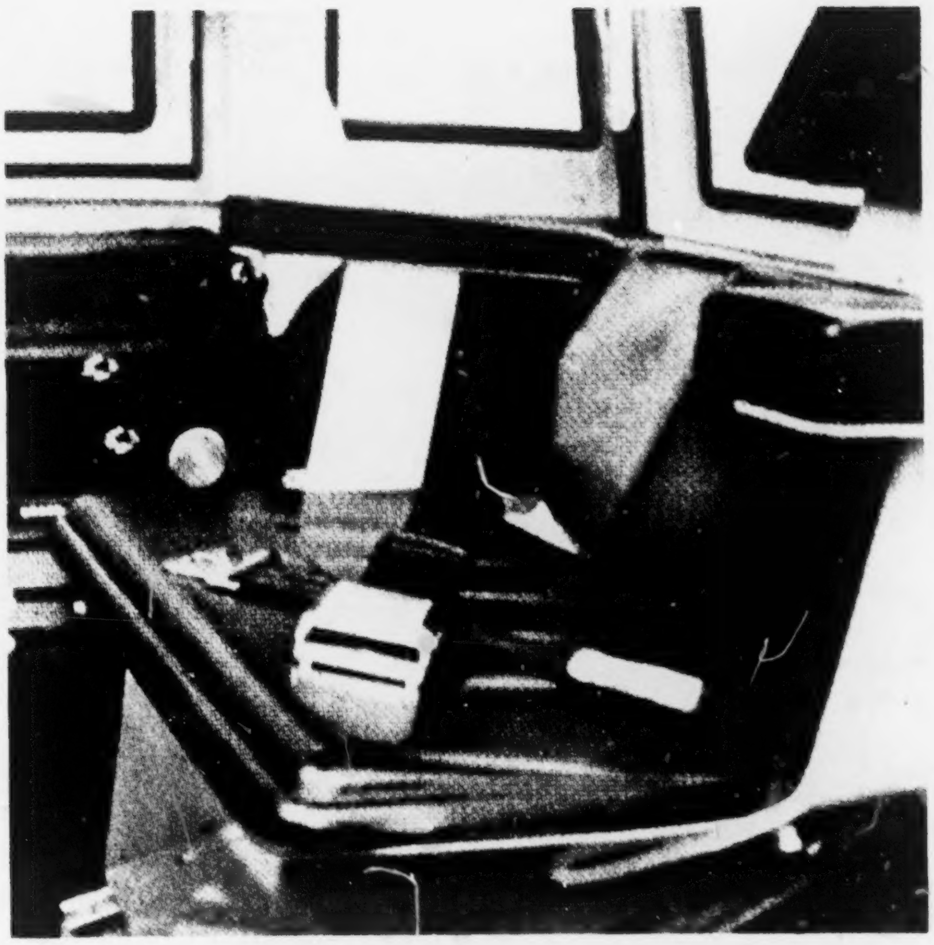
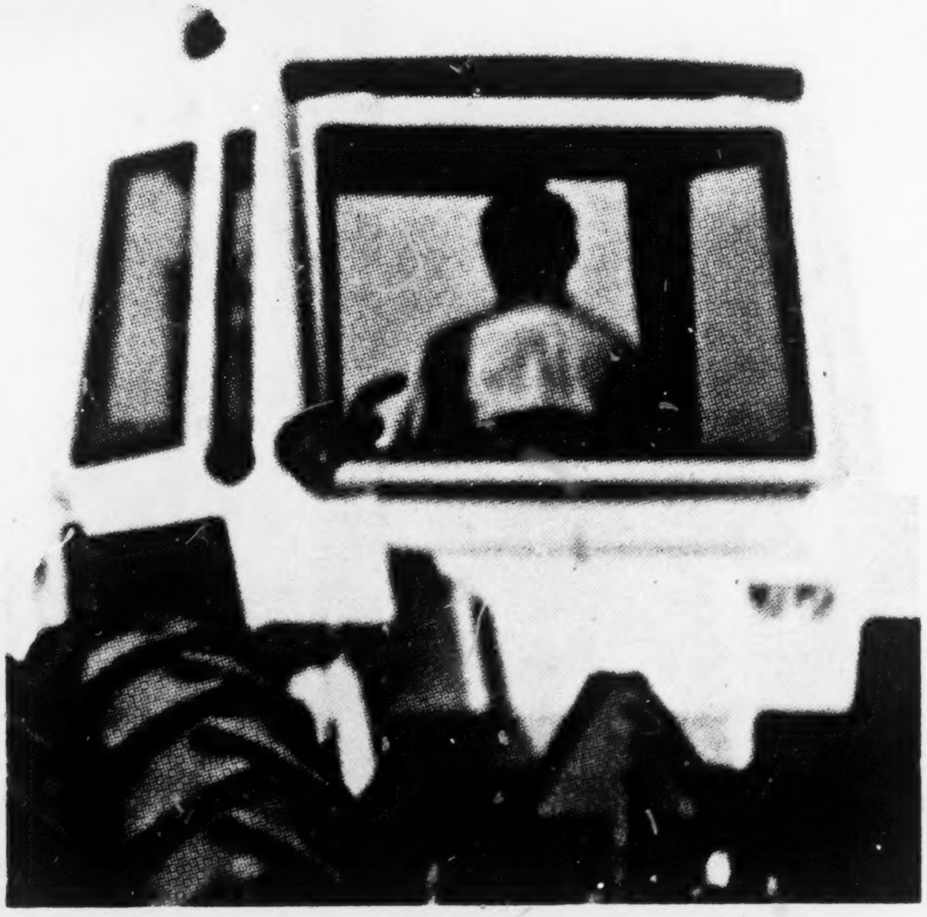


Figure 20.
Seat belts are standard equipment for tractors with cabs and rollbars.

Figure 21.
Tinted glass windows reduce glare. Sloped windows and rear air intake reduce noise levels within the cab.



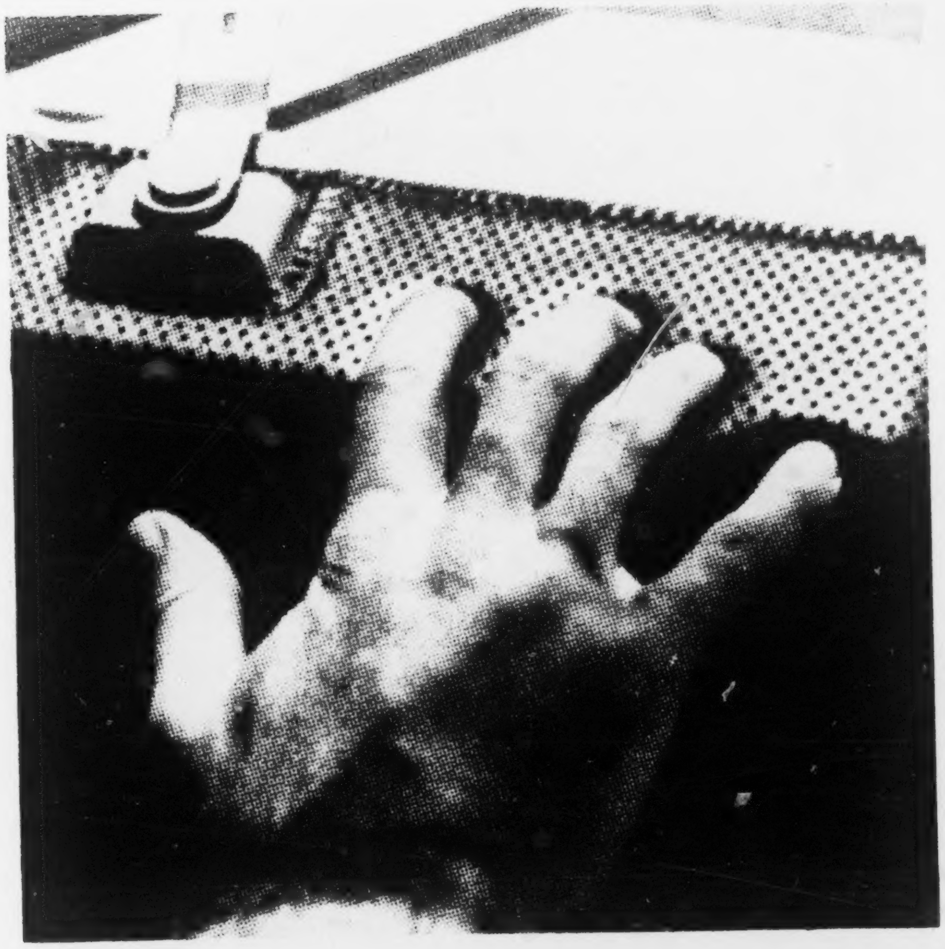
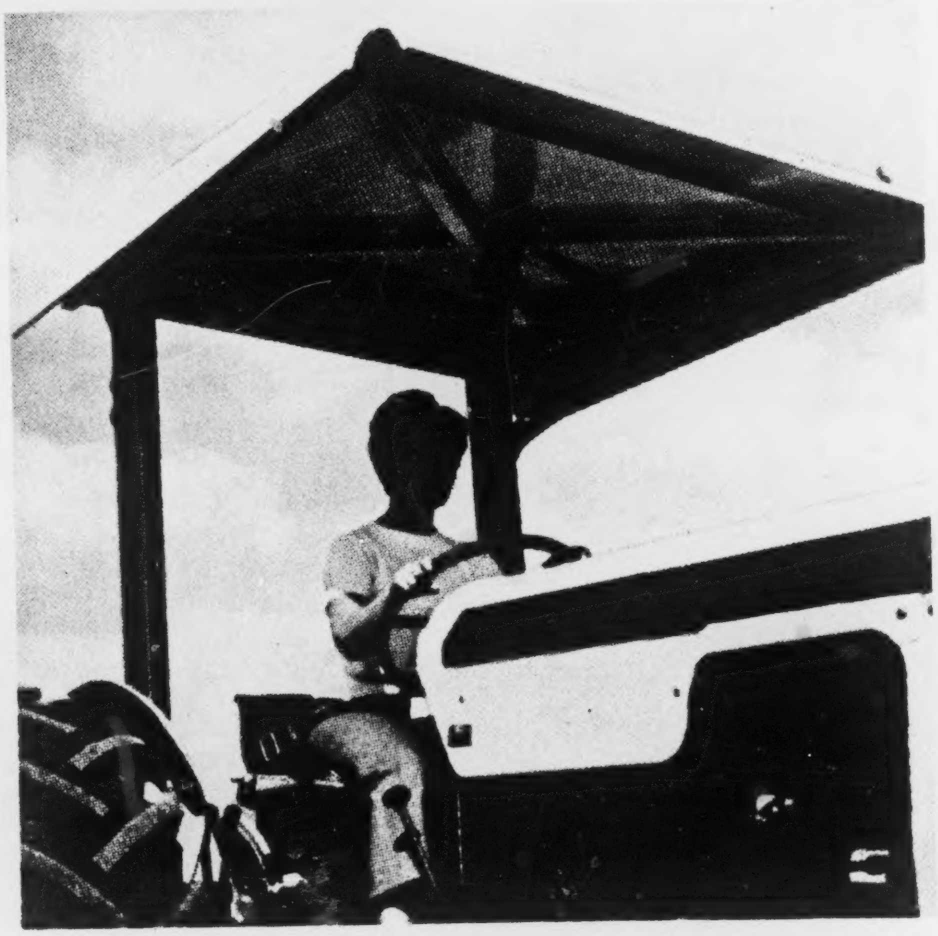


Figure 22.
Sound conditioning is foam padding covered with vinyl.

Figure 23.
Rollbars and canopy are available as attachments for most models.



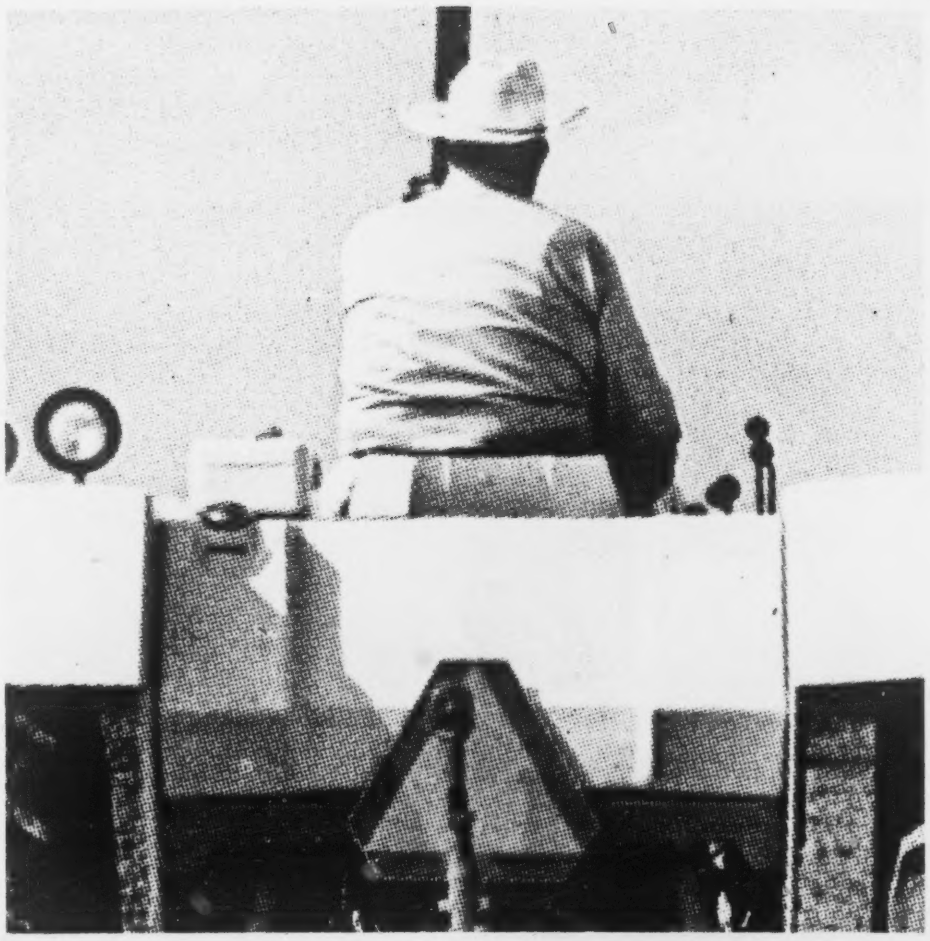
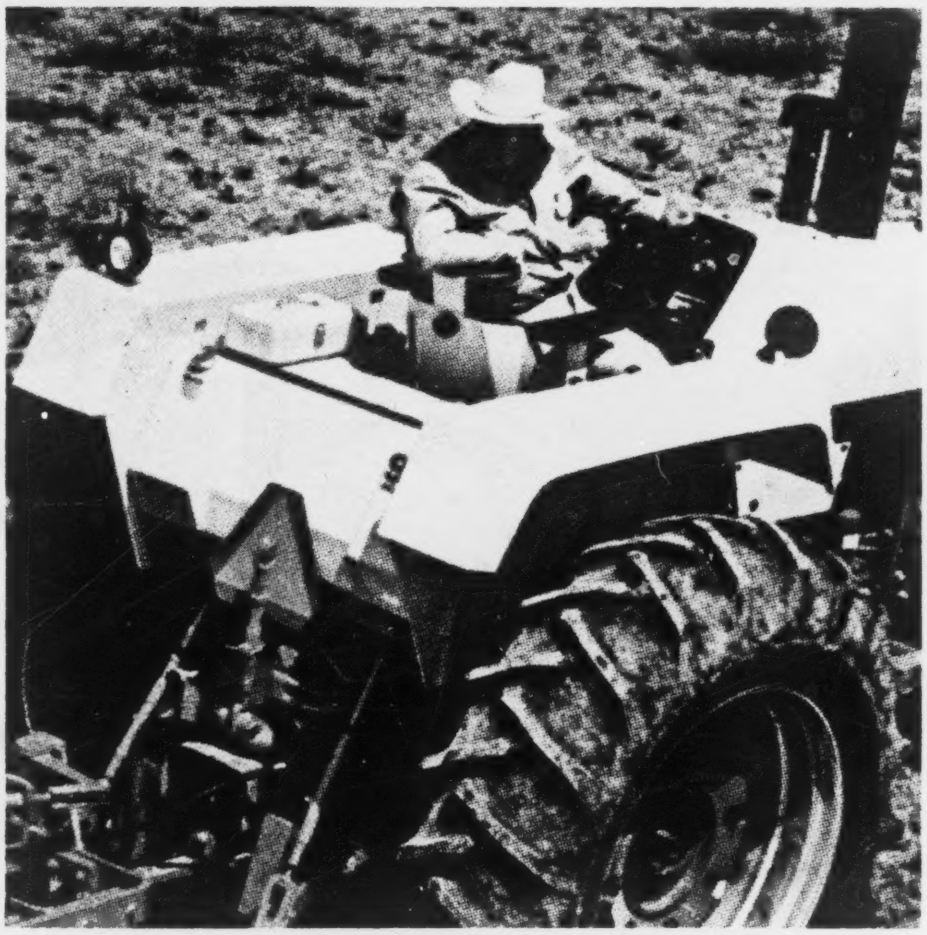


Figure 24.
Nylon fuel tank with spillproof cap
- eliminates rust
- eliminates electrical discharge
- resists fracture with increased shock absorption.

Figure 25.
Fenders are standard equipment and are designed as integral parts of the platform. SMV sign is standard equipment.



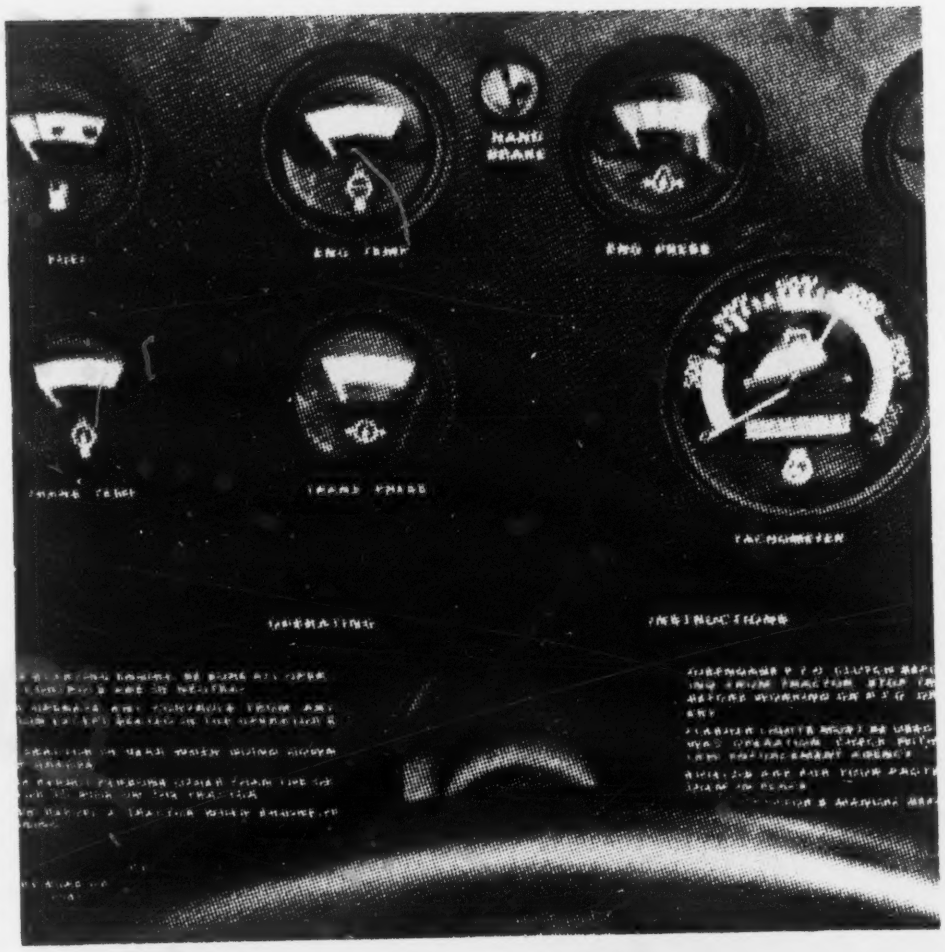
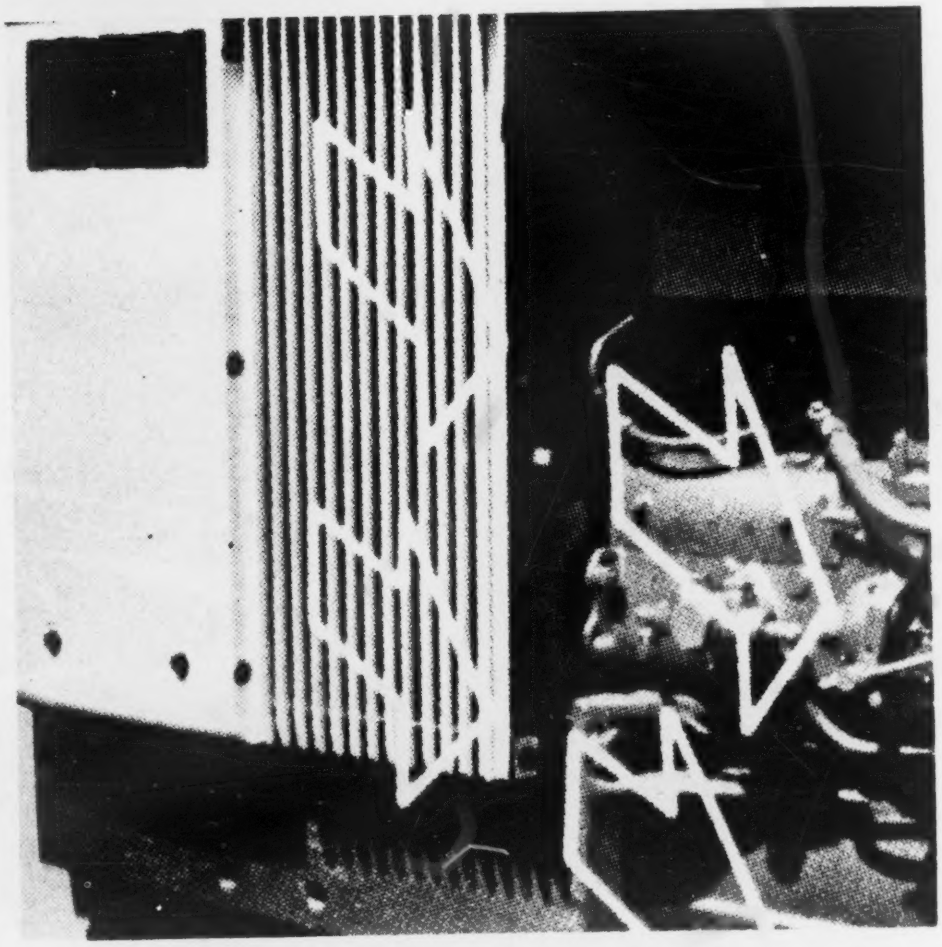

FUEL
ENG TEMP
HAND BRAKE
ENG PRESS
TRANS TEMP
TRANS PRESS
TACHOMETER
OPERATING
INSTRUCTIONS

Figure 26.
Back-lighted instruments have standard international coding and markings to identify function being monitored.

Figure 27.
Side louvers not only direct fan blast away from tractor, they also protect operator from fan, pulleys and belts.



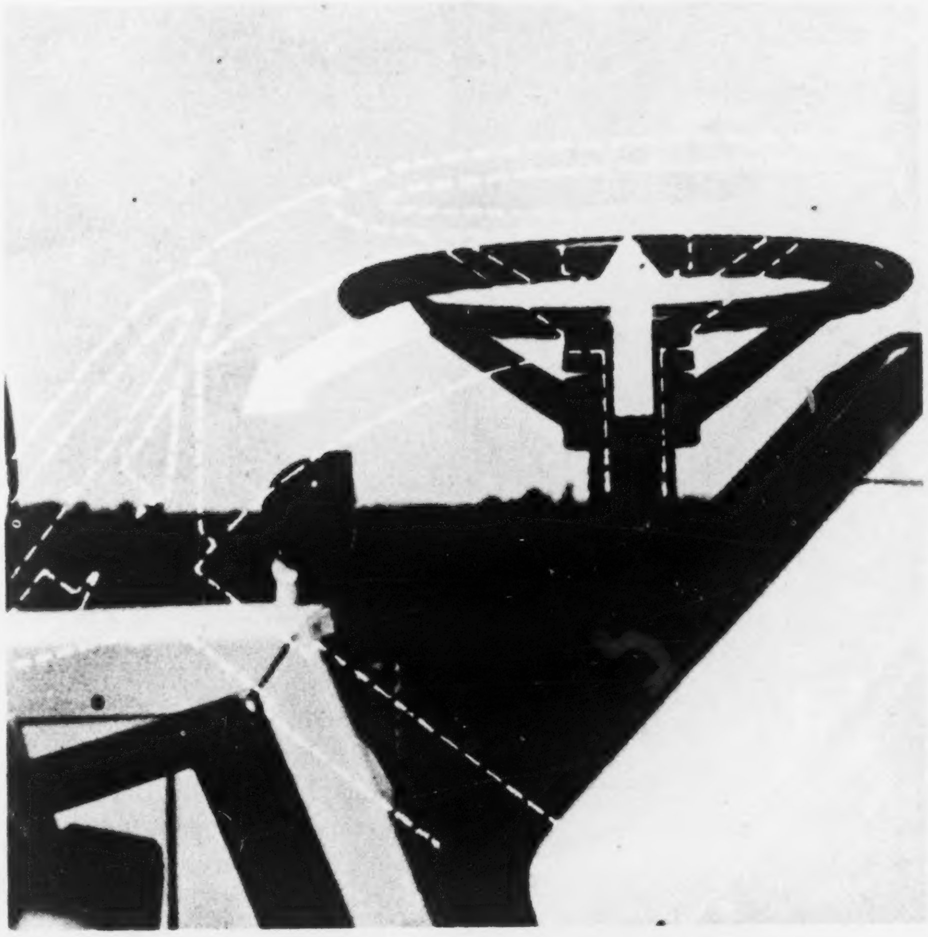
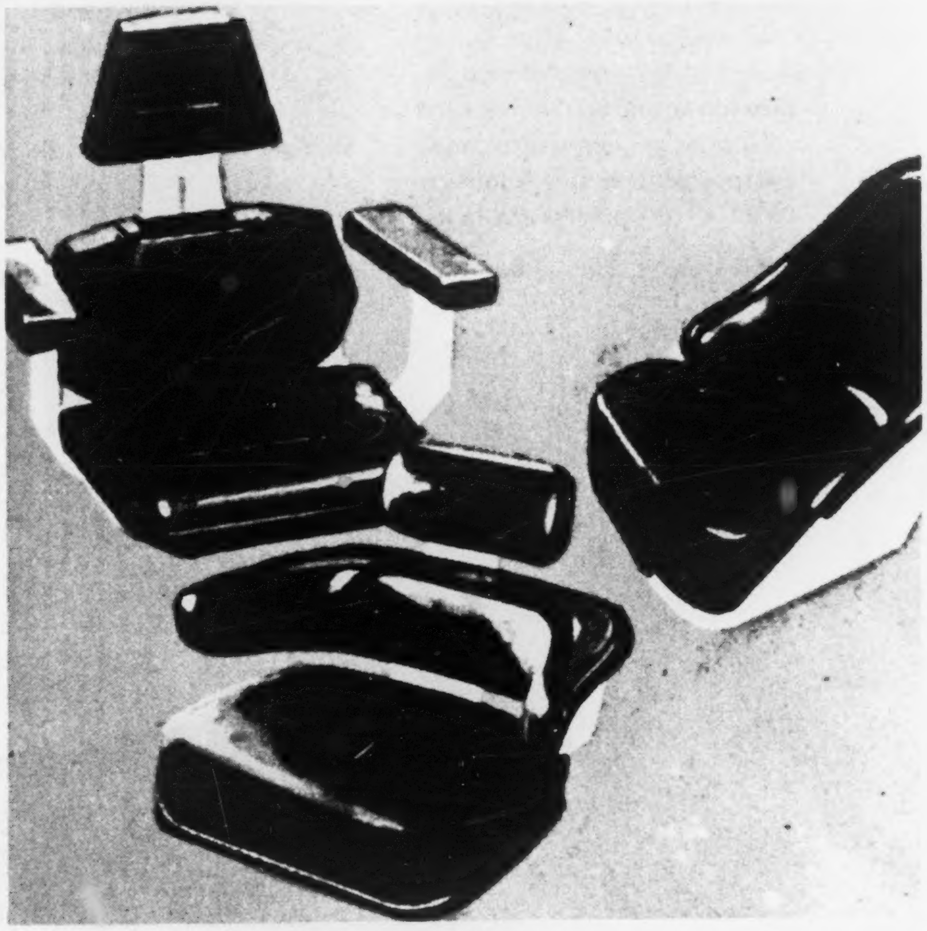


Figure 28.
Adjustable position and telescopic steering wheel for comfort of various sized operators.

Figure 29.
Choice of various types of seats at no extra customer expense to help improve comfort of operator.



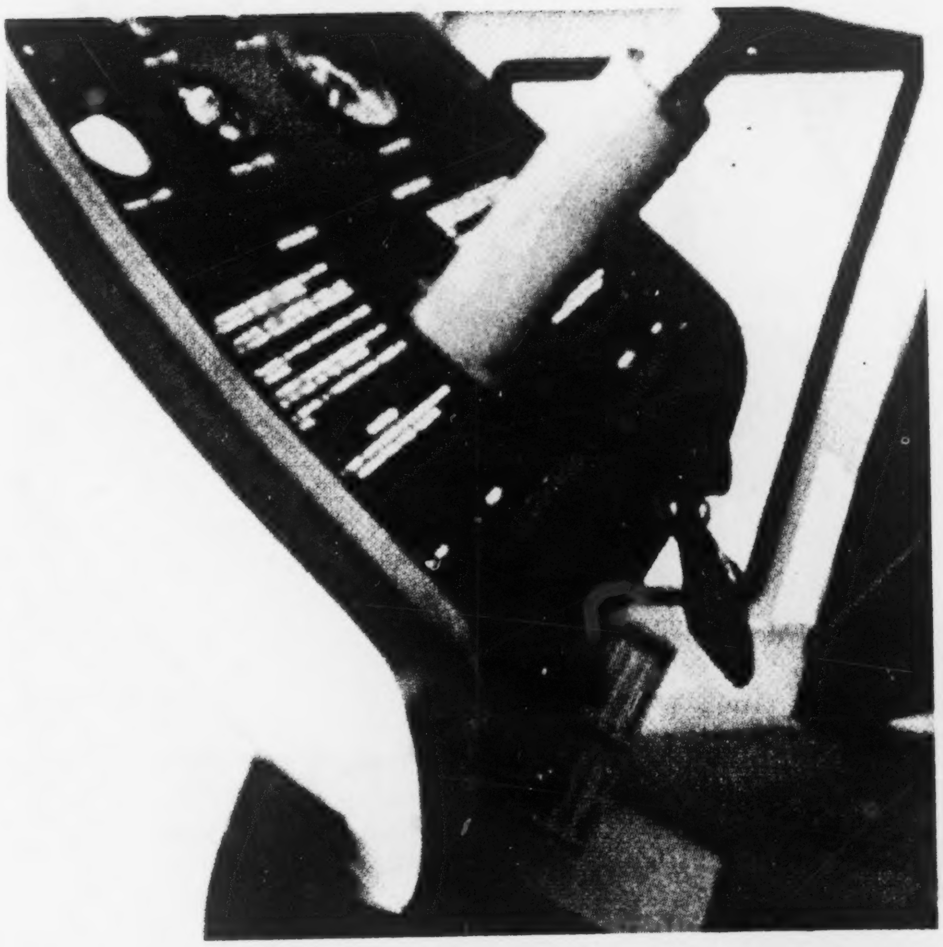
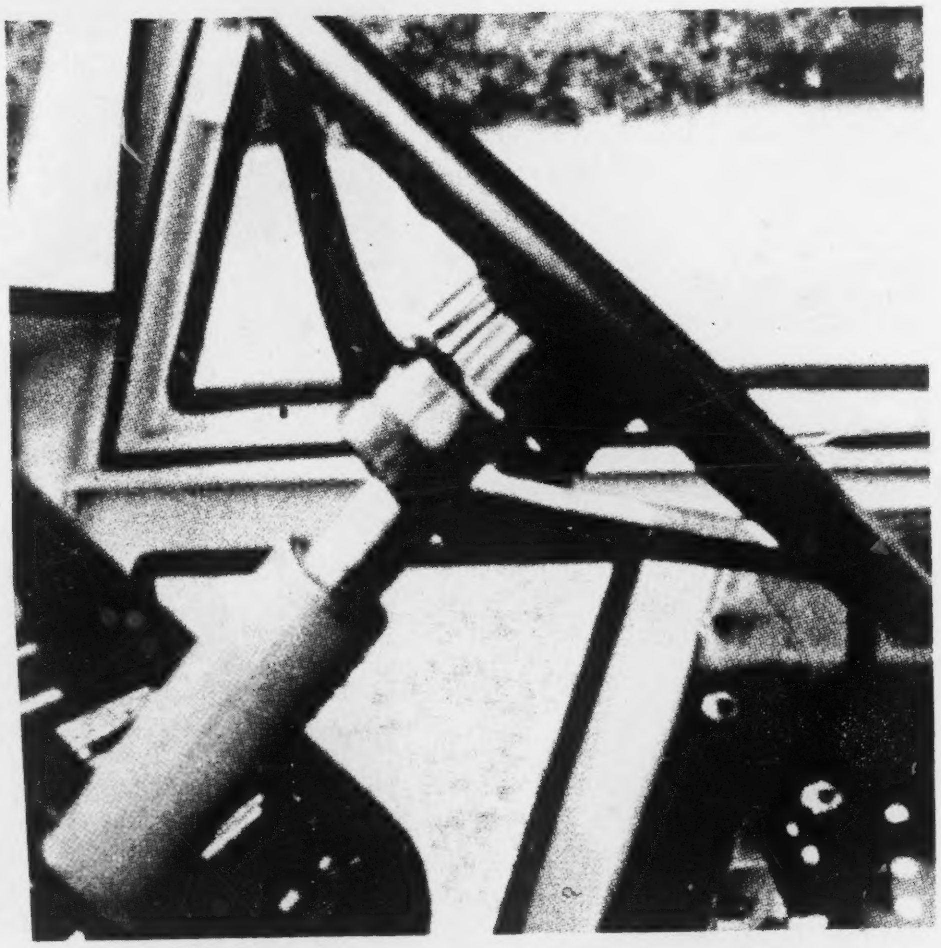


Figure 30.
Starting switch is an integral part of gear shift control to provide a neutral start position. Tractor may not be started with transmission in gear.

Figure 31.
Hydrostatic power steering is standard equipment.



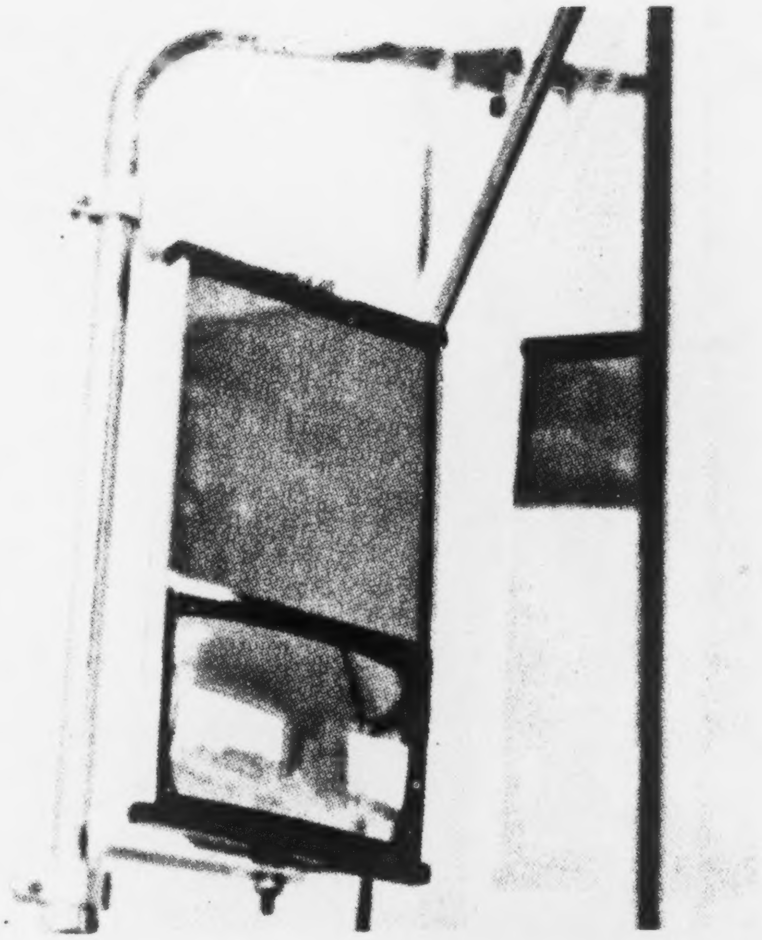


Figure 32.
Rear view mirror with convex, wide-angle view is useful on the highway as well as the field when wide implements are used.

Figure 33.
Hydraulic power brakes assure positive action for steering assist and stopping.

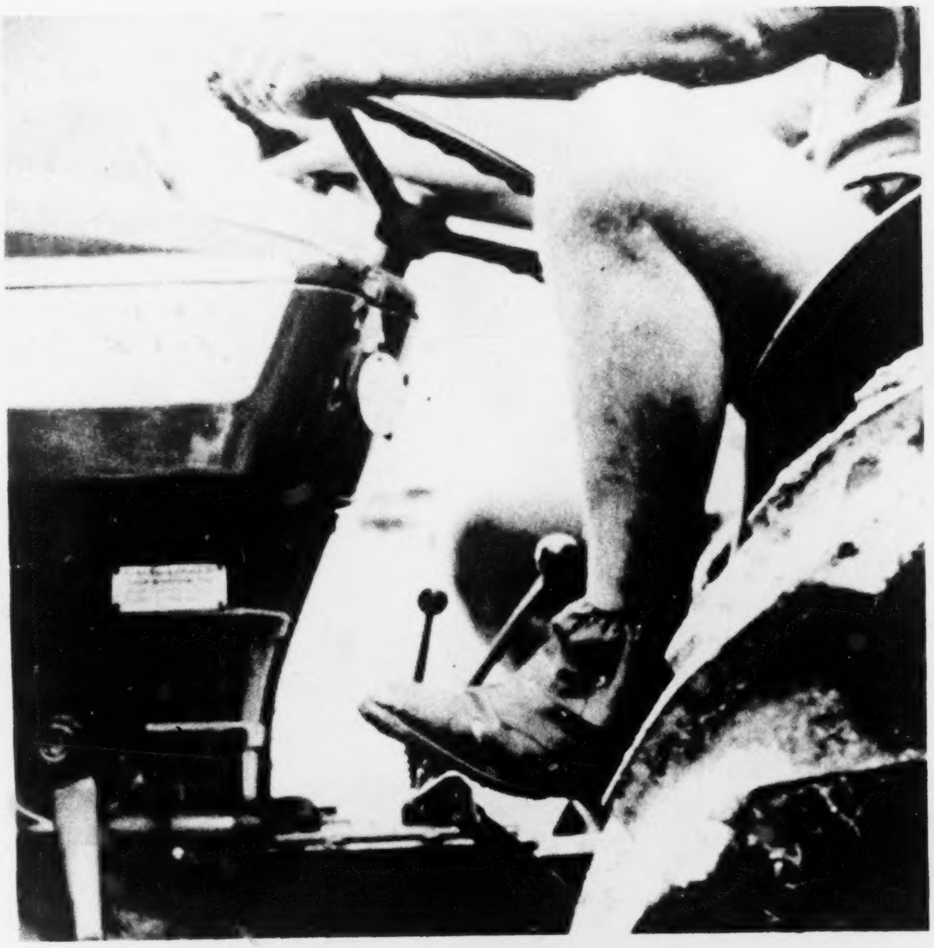
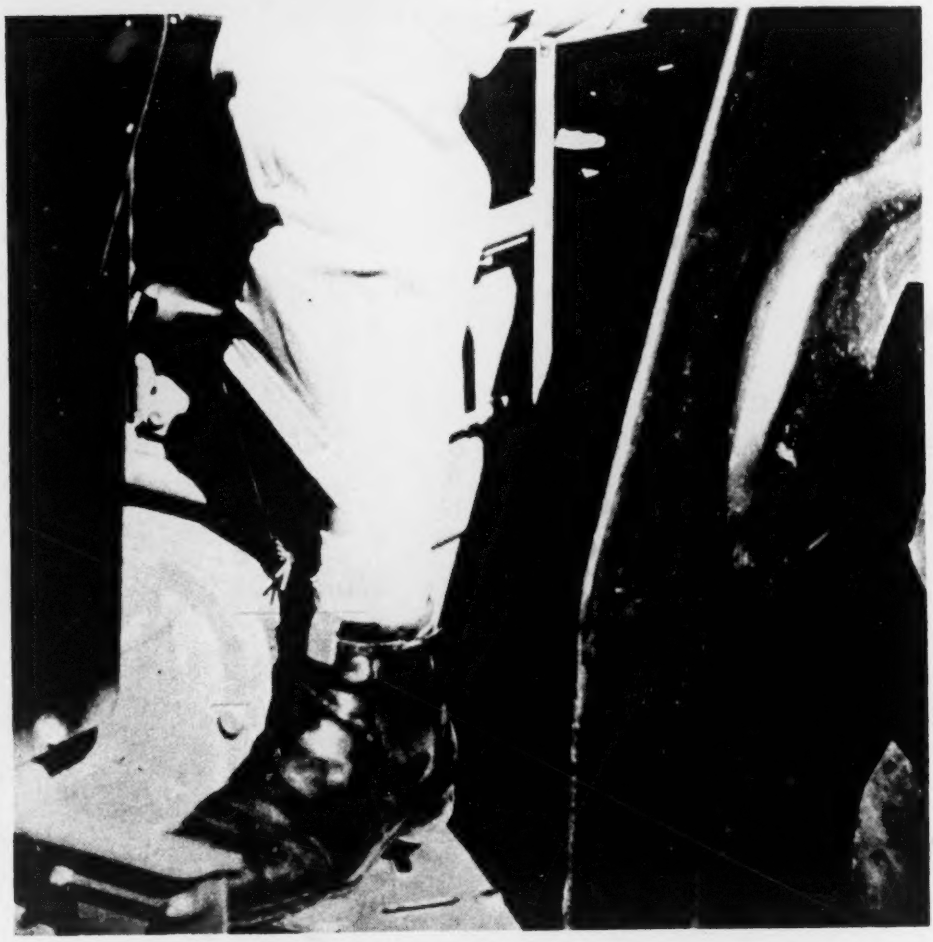


Figure 34.
Fatigue-inducing vertical clutch pedal.

Figure 35.
Vertical clutch is often stepped on when alighting. If transmission is accidentally left in gear, operator may be run over by left wheel. (Note pants leg is caught.)



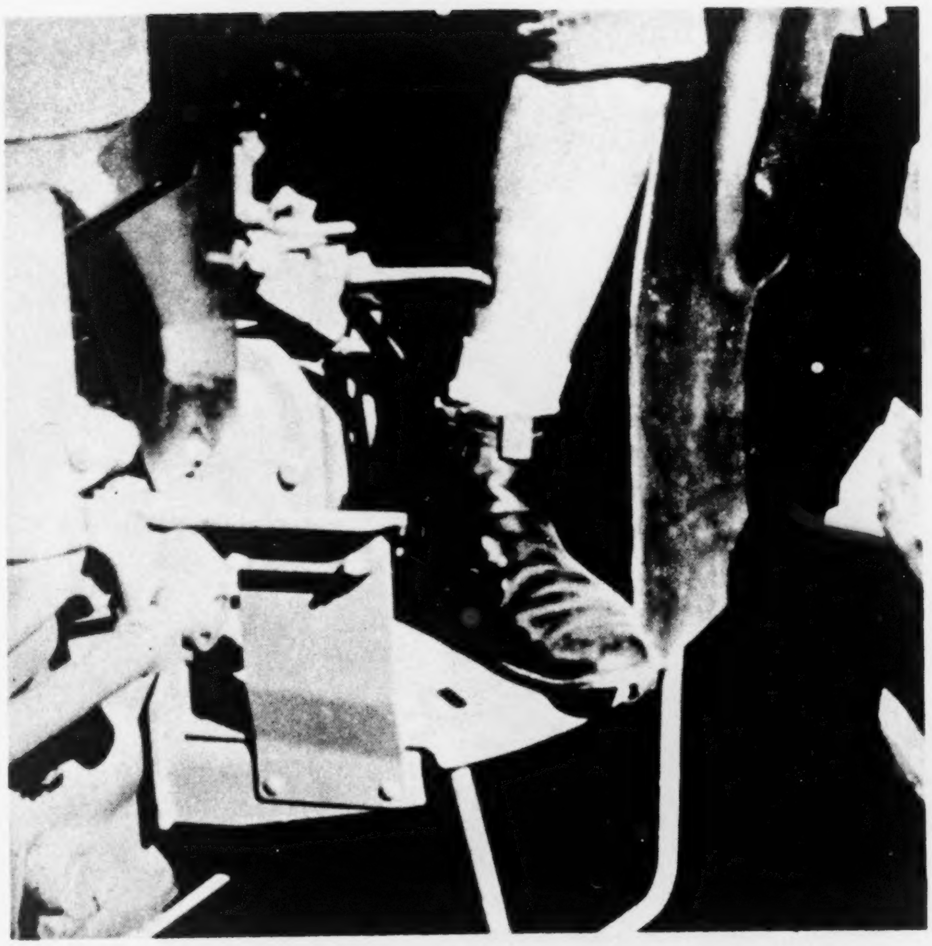


Figure 36.
Vertical clutch design discourages use of alighting step.

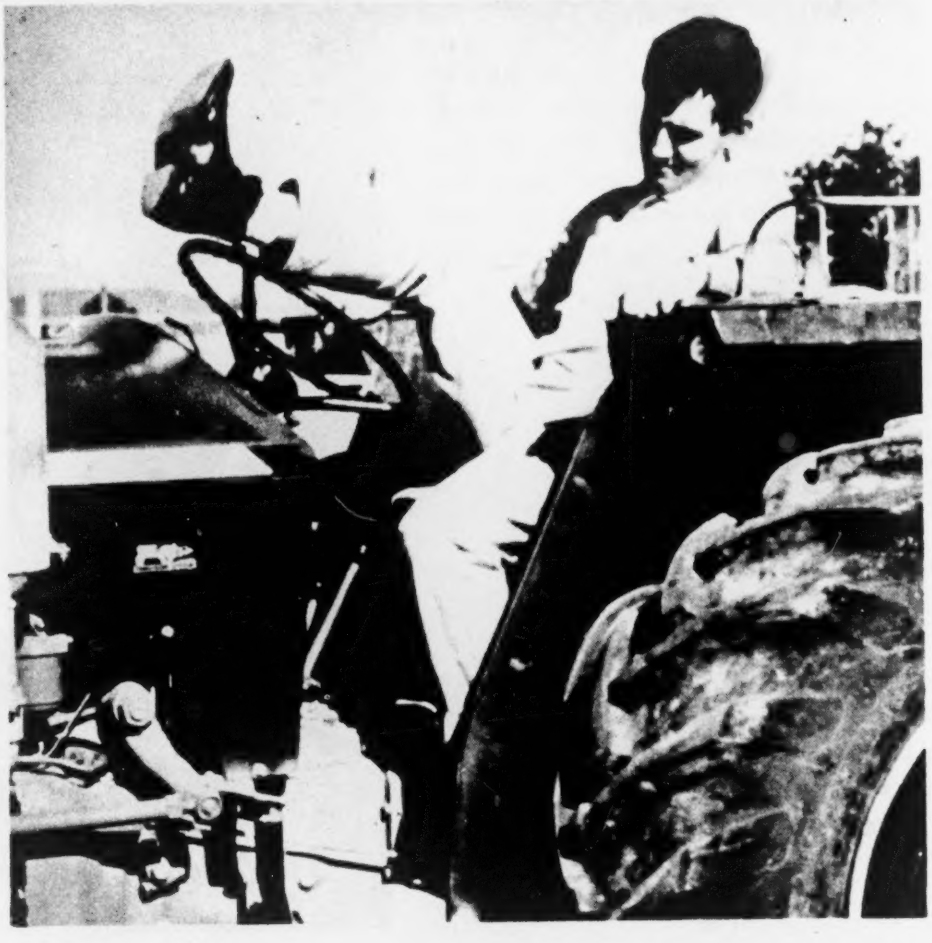


Figure 37.
A typical solution to alighting from such tractors.

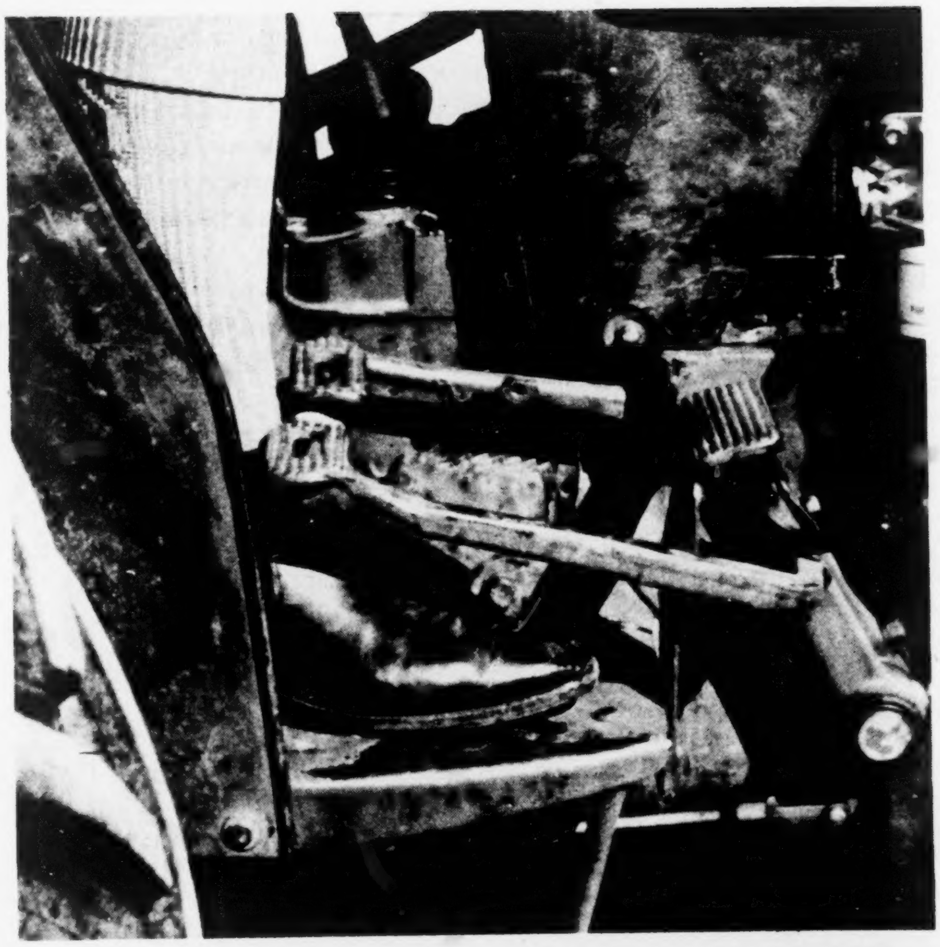
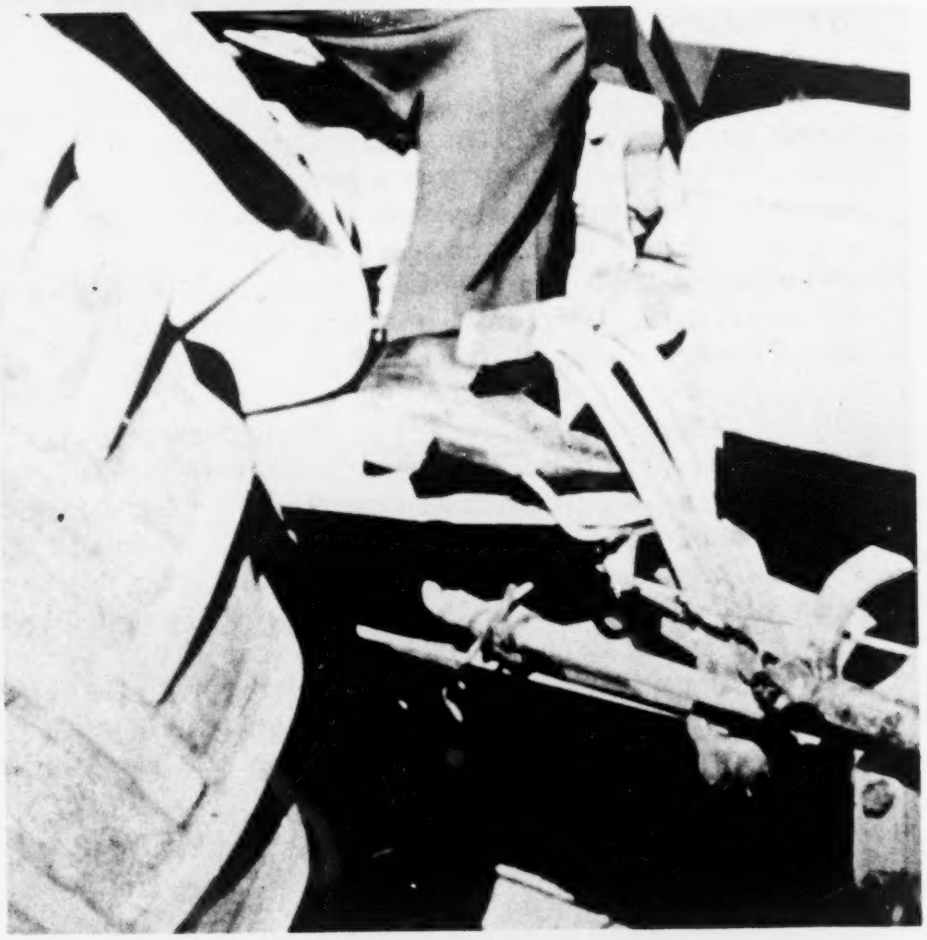


Figure 38.
Inappropriate location of brake pedals.

Figure 39.
Inappropriate location of brake lock.



is still relatively inaccessible. To refuel in the field, the operator often has to carry a five-gallon can of fuel over implement mountings, hoses, or other accessories to get to the tank and then must hold the can high in an awkward stance to pour the contents into the tank. Since he cannot see adequately from a low vantage point, the fuel may overflow down the side of the tractor, thereby creating a fire hazard as well as paint damage.

The trend to diesel and away from gasoline is in a safe direction, as is the newer practice of locating the tank in front of the radiator or at the rear. Some tanks now are made of nylon to permit greater deformation on impact and to prevent explosion due to electrical discharge.

Exploding tires have been pointed to by Gellatly as a hazard. No general recommendations are given as a possible solution (Appendix B:B81). None of the 789 fatalities analyzed by the NSC in their report on tractor fatalities was caused by tire blowouts, overinflations, or explosions. (105). Further study is warranted.

3.4.3 Tractor Design in General

Schnieder (Appendix A:A1), Wardle (Appendix A:A41), Gray (39), and Dieffenbach (40) are among those who have discussed the tractor and the development of tractor design.

While there are still a few tractors between 30 and 40 years old, they normally are used only as backup equipment or as stationary power sources. Wheeled tractors manufactured in 1940 were similar in appearance to those of today. Both tricycle and four-wheel tractors were available; had the operator's seat located generally above and behind the rear axle; were powered mostly by gasoline-burning, internal-combustion engines; had an average horsepower rating of 26 and a weight-to-horsepower ratio of about 150 lbs/belt horsepower; were equipped with electric starters; and, had a 536 RPM power take-off available. At least one tractor model, produced in 1940, had an advertised top speed of 28 mph.

Since 1940, tractor design swung first to the tricycle type tractor and then back to the "wider front-end models which now predominate on agricultural tractors." (Appendix A:A8). The diesel engine has been adopted to the point where it is used as the power source in the majority of tractors. The average engine horsepower increased to 75 while the average weight-to-horsepower ratio dropped to around 100 lb/belt HP. As pointed out earlier in this chapter, the center of gravity of today's tractor is believed to be not much different from the tractors of 1940, although there are some large four-wheel drive tractors on the market today with a center of gravity shifted more toward the front. According to a paper prepared for this report by Schnieder the following safety features have been added to tractors since 1940:

" 1. Power steering.

2. Power brakes as regular equipment.

3. A quick coupler which makes hooking up of equipment much safer and reduces the amount of jockeying required to attach implements.

4. An uncluttered platform.

5. PTO shielding and rotating shields in most implement power lines.

6. Shroud and shielding of the fan and alternator.

7. Adequate steps and handholds for safe mounting and dismounting.

8. A fuel tank location which keeps the fuel cooler with less danger of splashing fuel on hot engine while fueling.

9. Fenders as standard equipment.

10. Safety interlocks to prevent starting in gear.

11. An ether starting unit for use in cold weather.

12. A control location designed to eliminate finger pinching and reduce effort in movements.

13. Adequate lighting for visibility plus flashing warning lamp and rear lights and shielding instrument lights to reduce glare.

14. Use of hydraulic system to eliminate manual lifting by use of attachments.

15. A provision of front and rear weights when required for stability.

16. A power shift transmission which will hold on downgrade in all gears, no free wheeling.

17. A positive park lock.

18. Adjustable seats or controls.

19. Protective knobs on all hand controls, non-skid surface on all foot controls.

20. Screens to prevent accumulation of trash around heated areas.

21. The operator's manual with complete instructions and safety warnings supplemented by decals on the tractors.

22. Cigar or cigarette lighter with circuit breaker which permits lighting up with hand on wheel.

23. Horns on some tractors.

> "There are other features that also contribute to safety. One of these is that the safety canopy is designed such that it can be used with other implements. The canopy can have an enclosure for foul weather working.
>
> "Much work has been done on reducing tractor noise by reduced noise level mufflers. This also includes improved visibility due to the revised muffler and vertical air intake. Seatbelts are standard equipment wherever roll bars are used. An additional front ballast will be available to improve the stability with heavy rear mounted implements." (Appendix A:A9).

CHAPTER FOUR

4.0 Operator Caused Accidents and Injuries

In this Chapter the following topics are discussed:

- Biographical factors (age, sex, education level, and operating experience).
- Knowledge and skill requirements for tractor operation.
- Medical factors.
- Instruction in tractor operation.
- Operator certification.
- Non-operator victims of tractor crashes.

There is a striking absence of hard data on the human element in the man-machine-environment interface of agricultural tractor operation. Only a small number of individuals within the university community and within the manufacturing and insurance industries have attempted serious study of the problem in an organized manner. Additionally, data elements of farm tractor crashes for the most part lack uniformity in coverage and approach. (Appendix A:A230).

Lacking the required data base with an agreed upon set of definitions and a measure of exposure (exposure refers essentially to the "opportunity" to become involved in an accident), few of the results reported in the literature for biographical factors such as age, sex, educational level and operator experience can be considered conclusive.

Knowledge and skill requirements for effective tractor operation are currently based largely on technical opinion since a task analysis of agricultural tractor operation has yet to be reported.

Hard information on medical factors associated with tractor crash involvement is not available. One reason is that medical screening criteria for tractor operators have not been developed by the medical profession since tractor operators are exempt from licensing requirements in all States. Another reason for the lack of medical information is that there have been few clinical studies of tractor crashes.

Increased attention to tractor operator training has been noted since January 1968 when the Secretary of Labor announced the interim Hazardous Occupations in Agriculture Order. (47). There is little evidence of training program development for populations other than those required for 14- and 15-year old hired youths affected by the Hazardous Occupations in Agriculture Order. No evidence was found to indicate that training programs have been developed for the purpose of maintaining the proficiency of the tractor operator, or for remedial purposes following crashes or other tractor associated incidents. All of the training program outlines reviewed revealed deficiencies in content, some of them serious. These deficiencies are discussed below.

Little is known of the non-operator victim of tractor crashes, again pointing up the scarcity of hard data on the entire agricultural tractor crash problem.

4.1 Biographical Factors. As this term is used in this report, these factors include: (1) age, (2) sex, (3) educational level, and (4) operating experience.

4.1.1 Age. On the basis of data analyzed during the preparation of this report, there is no scientific basis for recommending age limits for the operation of agricultural tractors, and no evidence that any change should be made to the age threshold in the Hazardous Occupations in Agriculture Order.

An inverse relationship between age and accident frequency has been reported in studies in which age has been considered. In a study of the characteristics of 789 fatal tractor crashes, the National Safety Council reports that 27 percent of the 763 cases for which age was reported involved persons under 20 years of age. (105) Eighteen percent included persons in the age range 50-59, and 16 percent involved persons in the age range 60-69. These data were collected from 13 States between 1960 and 1965. In a study of the frequency and type of 100 tractor upsets in Nebraska from January 1, 1966 through December 31, 1969, 34 percent involved persons under 20 years of age; 18 percent, persons in the age range 50-59; and 9 percent, persons 60-69. (139). The 1960 Nebraska census showed 24 percent of the rural farm male population between 10 and 19 years old. Schnieder and Florell's data also showed the under-20 age group to have the greatest percentage of tractor upsets of any age group whether operating on highway or country road, farm road, or on a farmstead or in the field. An analysis of 1589 tractor accidents, all occurring on North Carolina highways during the five year period 1962-1966, revealed disproportionately high frequencies for persons below 20. (126).

A report of the 212 fatal and approximately 7,000 injury producing, but non-fatal, accidents directly involving farm tractors that occurred in Ohio during the period 1956-1960 showed that 24 percent involved persons under 20; 12 percent, persons between 50 and 60; and 17 percent, persons between 60 and 70. (79).

These examples, plus others reviewed during this study, indicate an age-accident picture not unlike that of the highway safety field. Thus, it may be inferred that the higher accident experience among young tractor operators, like motor vehicle drivers, may be associated with inexperience, while slowing of reaction time or some other measure of coordination may contribute to the increased frequency noted for those in the higher age ranges.

In a study, conducted for the National Highway Safety Bureau, to determine if age is a critical factor in assessing school bus operator performance, the following statement is made:

> ". . . the ability to predict [accidents] on the basis of age or any other variable for that matter, does not necessarily imply the existence of a causal relationship. Other factors generally associated with age, such as the number of years of driving experience, may have a more direct bearing on accident rates." (122:90).

As indicated previously, the Hazardous Occupations in Agriculture Order concerns the employment of youth under 16 years of age in certain farm jobs deemed particularly hazardous. These jobs included tractor operation. The Hazardous Occupations in Agriculture Order does not apply to youth working on a farm owned or operated by their parents or persons standing in place of their parents. Students in cooperative vocational education programs are also exempted from the Order. In June 1968, the Order was further amended to permit 14-and 15-year old youths to operate tractors and certain other farm machinery after they had completed training in its safe use. The training programs are conducted through the Federal Extension Service of the U.S. Department of Agriculture and its cooperative units. A further exemption to the Order permits 14-and 15-year old vocational-agriculture students to operate tractors and certain farm machinery after they have completed training in its safe use. These latter training programs are conducted by vocational-agriculture instructors certified in the safe operation of tractors and farm machinery.

The U.S. Department of Labor's Bureau of Labor Standards, over a two-year period (January 1, 1970 through December 31, 1971), is reviewing and evaluating the training exemptions to determine:

- Whether the use of protective frames, crush resistant cabs and other personal protective devices should be made a condition of these exemptions.

- Whether the training and supervisory requirements set forth in the exemptions should be modified.

In summary, the following point raised by McFarland in a discussion of age and motor vehicle operators is significant:

> ". . . Even if an inverse relationship between age and accident rates should be demonstrated conclusively, it might provide the basis for some sort of selection or screening procedures, but would not in itself provide any deeper understanding of accident causation. Understanding depends upon determination of the factors which are covariant with age and which contribute to the increase of accidents. Understanding of these covariant factors might permit the development of countermeasures specifically designed to control them (training, use of special equipment, special restrictions, etc.)."(19:52).

4.1.2 Sex. Studies of the relationship between sex and accidents in general have been limited, for the most part, to studies of motor vehicle populations. The National Safety Council report of 789 fatal tractor cases revealed 3 percent of the 782 cases upon which sex information was obtained involved females. (108). Roberts and Suggs found that less than 2 percent of the operators involved in 1589 tractor accidents occurring on North Carolina highways during the five-year period 1962-1966 were female. (126). Other studies report equally low involvement of females in tractor accidents. Donaldson, in his discussion of farm machinery accidents in Canada, points out that, except as children, females are rarely the victims of fatal farm machinery accidents. (23:89).

None of the studies reviewed by NHSB contain information on whether the males and females included in the samples were performing essentially the same tasks and were exposed to the same chance of injury. Thus, no basis exists for concluding that there are significant differences between males and females in tractor accident experience.

4.1.3 Educational Level. Information on educational level of victims of agricultural tractor accidents and fatalities is scarce and inconclusive. In the National Safety Council report of the characteristics of 789 tractor fatalities, data on educational level was not reported. (108). Some researchers who have investigated and reported on tractor accidents have collected data on educational level of the victim, but either have not reported the results of their findings, or have done so in such a manner as to prohibit the development of valid conclusions.

Although general intellectual ability is known to be associated with accidents in industrial and highway settings, there is no evidence to indicate that this finding would or would not apply to tractor populations.

4.1.4 Operating Experience. Willsey and Liljedahl, in their report based on interviews with 145 victims of non-fatal tractor overturns, observed that most of the operators would have to be considered experienced tractor operators. (193) However, some operators had spent relatively little time with the tractor which they were operating at the time of the upset. In the National Safety Council study of 789 tractor fatalities, of the 503 cases (64 percent) on whom information on operating experience was obtained, 95 percent reported experience of one or more years with a tractor. (108). Of the operators involved in the 100 tractor upsets studied by Schnieder and Florell, only 17 percent were considered to be inexperienced. (139:9). Roberts and Suggs made the following observation about tractor operator subjects under 20 years of age who were studied during an investigation of 1589 tractor accidents on North Carolina highways:

> ". . . It appears that insufficient training, inexperience and mental attitude of the operator regarding the tractor dynamics are the major factors underlying the high accident rates for this age group." (126:9).

Data available on the relationship between operating experience and tractor accidents are inconclusive. None of the studies reviewed provided detailed information such as the type of training received, the recency of the training, the type and quality of supervision received, or the precise characteristics of the tasks being performed. Until this and other information is available, it is not possible to demonstrate a relationship between the quantity and quality of operating experience and tractor accidents. Further, there is no conclusive evidence to suggest a relationship between licensed motor vehicle operators and tractor accidents on the highway. The hypothesis that tractor operators who hold valid drivers' licenses have fewer accidents when operating on the highway than those who are not licensed to drive has yet to be tested.

4.2 Knowledge and Skill Requirements for Tractor Operation. Unlike the motor vehicle, there are no legal requirements for operating tractors and other farm machinery and no tests of operating practices or performance are administered. An exception are those 14- and 15-year olds who desire to obtain an exemption to the Hazardous Occupations in Agriculture Order. These youth must complete successfully one of the approved programs of instruction in safe tractor operation. (146, 96).

Although there is no record of anyone having conducted a task analysis of agricultural tractor operation, some related activity has taken place. Personnel at the Accident Prevention Laboratory at The University of Iowa (Oakdale Campus) have done work in analyzing operator control action and work pattern diagrams for the lawn and garden tractor with hydrostatic transmission and mowing unit, for snow blowers, and for certain farm machinery operations. Other examples include the development of an Operational Sequence Diagram depicting the sequence of major normal events in a driver's operation of a school bus by Dunlap and Associates, Inc., (122:24-31). and the suggestions for developing driving performance analysis advanced by the Development Education and Training Research Institute of The American University. (76). Procedures for conducting task analyses have been worked out in considerable detail for complex man-machine systems. A general guide to the analysis is provided by Chapanis in a chapter entitled "Systems Staffing," of Systems Psychology. (20).

A description of effective tractor operation is needed, stated in terms of what the operator must do, that is, what behavior is required. These behaviors form the basis of performance objectives to be achieved through instruction in tractor operation. From these performance objectives may be derived the knowledges, skills, habits and attitudes that enable the trainee to attain performance objectives.

In discussing the chronology of training development, Hunter makes this statement:

> "The critical requirement of any technique is that it collects information from the job itself, to encourage validity, rather than from such derivative sources as personal recollections or published documents. The latter sources provide valuable leads for constructing a preliminary instrument, but complete and timely information is available only at the job site. If this sounds like a statement of the obvious, it is only necessary to recall that many training programs do not start with a description of operational requirements." (55:2).

Although successful performance of the identified tractor operator tasks may be used as objectives of tractor operator training programs, these programs must also be concerned with how a person learns to perform the tasks. That is, it may be necessary for an individual to acquire certain prerequisite skills, knowledges, or attitudes in order to be able or motivated to perform them properly. The acquisition of these prerequisites may well constitute a major portion of a tractor operator training program. Consequently for evaluating training program content, the task analysis should be done in such a way that the prerequisite skills, knowledge and attitudes for each task become apparent and can be identified.

Performance characteristics can more readily be drawn up for machines than for those who operate them. However, the development of performance characteristics for the tractor operator is a prerequisite to identifying knowledge and skill requirements for tractor operators and to developing programs of instruction capable of being evaluated in terms of a reduction in tractor crashes.

4.3 Medical Factors. No studies appear to have been made relating to screening factors for certifying tractor operators, probably because tractor operators are not required to be examined or licensed.

The National Safety Council report of 789 fatal tractor cases contains information on "driver human factors" for only 24 (or 3 percent) of the cases. Of these 24 cases, "physical condition of the operator" is indicated for only 8 percent of the victims. (105:7). The report does not define "physical condition of the operator." In the Nebraska study of 100 tractor upsets, "condition of operator" is listed as a suspected cause of the accident in eight instances. As with the National Safety Council report, however, the term "condition of operator" is not defined.

4.4 Instruction in Tractor Operation. There is no such phenomenon as a "safe" individual. An individual can be trained to perform selected specific tasks so that the probability of his performing them with low risk to others and to himself is increased. For example, Donaldson, in commenting upon education and safety programs for operators of farm machinery makes this statement.

> ". . . By experience and training, it is possible to develop in man learned responses which might improve the accuracy and speed of his reactions. Similarly, by training and education it seems likely that it is possible to alter to some extent the perception and judgment of man in his role of machine operator. This might be achieved by improving basic knowledge and information of the operator so that his awareness is increased, permitting observations to be more significant, analysis to be more comprehensive, the subsequent decision more accurate, and the action taken more appropriate." (23:53-54).

Without discounting the importance of training, it is costly and results cannot be anticipated with confidence. Thus, while improved training should continue, it will not, by itself, necessarily result in immediate payoff in a reduction in deaths and injuries arising out of tractor crashes.

The most effective way of combating the effects of an injury producing agent is to remove the hazards associated with it. While this is the "ideal" solution, such removal is not always feasible or practicable. It simply is not feasible to attempt to remove all of the hazards associated with those operations in which tractors are used. Some of those hazards which remain following redesign or modification of equipment, or improvement to work methods, can be eliminated or otherwise controlled by protecting the individual who works with the equipment. Operator protection in the form of a crashworthy cab, overturn protection and seat belts will not prevent an overturn, but will significantly increase the chances of survival of the tractor occupant. In the real world, it is not always possible to remove all or even most of the actual or potential hazards associated with an operation or to provide full protection against these hazards. Accordingly, personnel who operate tractors, or who work in their presence, should be instructed to do so in such a manner that will minimize the probability of their being killed or injured if a failure occurs in the system. This is the role of training in a program designed to reduce the frequency and severity of tractor crashes.

As described later, informal instruction is available from the parents or guardians of farm youth, and from manufacturers' representatives and dealers when the tractor, or piece of equipment to be used in combination with the tractor, is purchased. Dealers attempt to assure themselves that the purchaser is familiar with the controls and certain characteristics of the equipment. A checklist frequently is used to make certain that key points are covered during this orientation to the new equipment.

4.4.1 Formal Programs of Instruction in Tractor Operation

A. Vocational Agriculture Training Programs (Safe Tractor Operation; Safe Farm Machinery Operation). Vocational-agriculture teachers are permitted to sign exemption certificates to the Hazardous Occupations in Agriculture Order for 14-and 15-year old youth, provided that these youth have successfully completed a training program. The training program to meet this requirement was developed for the U.S. Office of Education by the Rural Manpower Center of Michigan State University. (146). The tractor program requires a minimum of 15 hours of instruction. Twenty-five hours of instruction is considered desirable, and additional time may be used if the teacher considers it necessary for his particular class.

The instructional program outline includes the major topics shown below.

	Topic	Suggested Instructional Time
I (R)	Importance of Tractor Safety	1 hour
II	Pre-Operating Procedures	2 hours
III	Adjustments to Meet Operating Needs	3 hours

	Topic	Suggested Instructional Time
IV	Starting and Stopping Tractor Engine	2 hours
V (R)	Controlling Movement	2 hours
VI (R)	Hitching to Tractor Operated Equipment	3 hours
VII (R)	Operating Under Field Conditions	6 hours
VIII (R)	Operating Under Highway Conditions	3 hours
IX	Unhitching Equipment	1 hour
X	Refueling	1 hour

* Instruction must be provided in those subjects which are preceded by an (R).

The objectives of this training program are to:

- Develop skills needed for safe tractor operation.
- Develop understanding of principles of safe tractor operation.

The student is eligible to receive a certificate only after he has completed the 15 or more hours of instruction, completed successfully both the written and practical tests for safe tractor operation, and has satisfied his instructor that he is able to operate the equipment safely.

B. 4-H Tractor Care and Safety Program. The 4-H Tractor Care and Safety Program is conducted by the Extension Service of the State agricultural colleges with the U.S. Department of Agriculture cooperating. Starting with the 1964 4-H Club Year, a completely new set of literature was developed for use by members and leaders in the 4-H Tractor Care and Safety Program. (96, 97, 98, 99, 100). A first year book (tractor project) for younger members is designed to acquaint them with the tractor and to emphasize some of the fundamentals of safe tractor operation. The subject matter is written at the sixth-grade level in the first year book and advances progressively with each book. The units included in the first, second, third, and fourth and advanced years are shown below:

FIRST YEAR - TRACTOR PROJECT. Units: 1. Learning How To Be Safe; 2. What Makes an Engine Run; 3. Nuts, Bolts, Screws, and Rivets; 4. The Instrument Panel; 5. Controls for Your

Tractor; 6. Daily Maintenance and Safety Check; 7. Starting and Stopping Your Tractor; 8. Clean Air for Your Engine; 9. Periodic Lubrication and Maintenance.

SECOND YEAR - TRACTOR PROJECT. Units: 1. Tractor Safety on the Farm; 2. Oil for the Engine; 3. Mixing Fuel and Air; 4. Battery Service and Spark Plugs; 5. Cooling Systems for Engines; 6. Care of Tires; 7. General Lubrication; 8. Tractor Records and Operating Costs.

THIRD YEAR - TRACTOR PROJECT. Units: 1. Tractor Safety on the Highway; 2. Engine Ignition Systems; 3. Hitches, PTO, and Hydraulic Controls; 4. Steering, Brakes, and Front Wheels; 5. Valves and Valve Service; 6. Power Transmissions; 7. Winter Care and Trouble Shooting; 8. Tractor Records and Ownership Costs.

FOURTH YEAR AND ADVANCED YEARS - MACHINERY PROJECTS. Units: 1. Safe Use of Farm Machinery; 2. Transmitting Power; 3. Tools For Breaking the Soil; 4. Applicators For Chemicals; 5. Servicing Seed Planters; 6. Cutters for Crops; 7. Seed Separation; 8. Farm Machinery Management.

A youth under 16 may be exempt from the Hazardous Occupations in Agriculture Order if he has successfully completed a 10-hour program of instruction which includes the following units of the 4-H Tractor Care and Safety Program:

First-Year Manual: Unit 1 - Learning How To Be Safe; Unit 4 - The Instrument Panel; Unit 5 - Controls for Your Tractor; Unit 6 - Daily Maintenance and Safety Check; and Unit 7 - Starting and Stopping Your Tractor.

Second-Year Manual: Unit 1 - Tractor Safety on the Farm.

Third-Year Manual: Unit 1 - Tractor Safety on the Highway; and Unit 3 - Hitches, PTO, and Hydraulic Controls.

Youth under 16 must also pass a written examination on tractor safety and demonstrate the ability to operate a tractor safely with a two-wheel trailed implement on a course similar to one of the 4-H Tractor Operator's Contest Courses.

During fiscal year 1969, a total of 63,013 4-H members (61,865 boys and 1,148 girls) were enrolled in the 4-H Tractor Care and Safety Program. (182:29).

4.4.2 Other Information Sources

A. National Safety Council

The Vocational Agriculture Training Program in Safe Tractor Operation and Safe Farm Machinery Operation, and the 4-H Tractor

Care and Safety Program are broad in scope and have multiple objectives. By way of contrast, the National Safety Council, in 1968, introduced a Tractor Overturn Prevention and Protection (TOPP) program, through which it hopes to accomplish the following objectives:

- Decrease the number of tractor overturns by an intensive public information effort on safe operating procedures.
- Curtail deaths and injuries from overturn by encouraging wide-scale use of operator protection such as protective frames, crush-resistant cabs and seat belts.

TOPP kits have been distributed to some 400 radio and television stations, and to some 240 agriculture publications. A special transcription and a set of color slides accompany the kits for radio and television respectively. A story on the development of tractor overturn protection is provided to editors. In addition, more than 500 TOPP kits have been sent to directors of extension, State 4-H and vocational-agriculture leaders; members of the Farm Conference of the National Safety Council; safety specialists and extension engineers; State heads of Farm Bureau, Grange and Farmers Union; leaders of rural women's groups; and farm equipment manufacturers.

Through its TOPP program, the National Safety Council hopes to reduce dramatically both the frequency of tractor overturns and the severity of the injuries sustained (studies show that 6 in 10 tractor fatalities involve overturns). The TOPP program is being promoted among highway maintenance departments as well as among farm populations. To support the TOPP program with factual data, the National Safety Council has supported and is continuing to support data collection efforts regarding tractor overturns in several States.

B. Future Farmers of America (FFA). FFA members, through their chapter activities, are in a position to provide leadership in rural communities. Most FFA chapters sponsor activities designed to promote farm and home safety, fire prevention and safe driving. Agricultural tractor safety is included in these activities. In order to stimulate interest in these activities, the FFA Foundation sponsors a nationwide program of farm safety awards to recognize those chapters that do the most outstanding work. A handbook entitled FFA at Work for Safety (25) provides resource material for teaching safety to FFA members, along with suggestions for safety activities.

C. Land-Grant Universities. Many of this nation's land-grant universities publish periodic reports on accidents, including tractor accidents, and disseminate these to the farm population. Specific examples are the reports prepared and distributed by the University of Nebraska (136) and The Ohio State University. (120).

Many of the land-grant universities also develop and distribute instructional materials on farm machinery safety to schools and to farm groups. A specific example of such a training aid is one developed and distributed by The Ohio State University. It consists of a brochure and a set of 35mm color slides of tractor accidents that occurred within that State. Instructions for avoiding the types of tractor accidents depicted in the brochure and in the slides are provided. Another activity organized and sponsored by the land-grant universities and designed to reach large numbers of the farm population are tractor power and safety demonstrations, many conducted in conjunction with county and State fairs. The University of Nebraska, for example, initiated a Tractor Power and Safety Day in 1952. This annual affair now averages some 15,000 attendance. Other activities in which land-grant universities are involved include administration of hearing tests to farm populations and the promotion of hearing conservation programs among these same populations.

D. Farm and Industrial Equipment Institute (FIEI). Through the FIEI and its contacts with various other interested groups, the member companies have promoted safe operation of equipment, including tractors. This has been done by publishing the promotional piece Tips for Safe Tractor Operation, by developing and promoting the use of safety messages to be placed on equipment, by promoting safety through publications, radio and television, and by preparing, in conjunction with the National Safety Council, the Safe Corn Harvest and Tractor Safety Kits. (27). Large numbers of the farm population participate in and observe the tractor driving contests, field days, and tractor power and safety demonstrations.

L. W. Randt, Safety Program Coordinator of FIEI, has summarized these activities thusly:

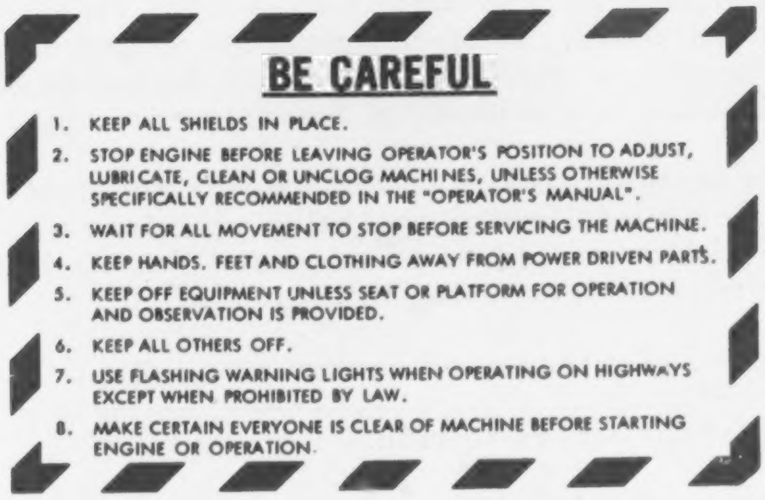
> ". . . the FIEI has provided support for safety education programs in tractor and harvest machine safety conducted by Future Farmers of America chapters. FIEI has also cooperated with the American Association of Agricultural Engineering and Vocational Agriculture in developing comprehensive texts and teaching aids in the area of machinery operation, maintenance and safety. Twenty States representing 67 percent of the Vocational Agriculture teachers in the United States use these materials. "(Appendix B: B-50).

E. Industry. Manufacturers are a major source of information for tractor operator training programs. Manufacturers encourage and promote the safe operation of their equipment through operator's manuals, product guides, service manuals and setting up instructions. Through external publications to their dealers, the manufacturers attempt to help farm customers to keep abreast of new farm practices.

Sales and service training for dealers and customers include the safe operation and maintenance of equipment. Farm equipment dealers frequently make tractors and implements available to local FFA, 4-H, and vocational-agriculture groups for operator training programs. Mr. Bert Andren, Assistant General Manager, Product Development, Ford Tractor Operations,has pointed to the fact that his company has operated two dealer training farms, one for more than a decade and one for a few years less than that. A portion of each formal training program is a short course in the safe operation of a tractor. More than 12,000 dealers, members of dealer organizations, and tractor customers have been through this training program. (Appendix B:B-120).

F. Warnings on Equipment. Still another source of information for the operator are the decals bearing warnings and operating instructions that are placed on new machines. See Figure 40. These, of course, have a limited "life" since with time and weather they tend to flake off or to become coated with grease or other substances and thus become illegible.

There are no studies or record of the extent to which tractor operators review the instructions and warnings posted on equipment.



BE CAREFUL

1. KEEP ALL SHIELDS IN PLACE.
2. STOP ENGINE BEFORE LEAVING OPERATOR'S POSITION TO ADJUST, LUBRICATE, CLEAN OR UNCLOG MACHINES, UNLESS OTHERWISE SPECIFICALLY RECOMMENDED IN THE "OPERATOR'S MANUAL".
3. WAIT FOR ALL MOVEMENT TO STOP BEFORE SERVICING THE MACHINE.
4. KEEP HANDS, FEET AND CLOTHING AWAY FROM POWER DRIVEN PARTS.
5. KEEP OFF EQUIPMENT UNLESS SEAT OR PLATFORM FOR OPERATION AND OBSERVATION IS PROVIDED.
6. KEEP ALL OTHERS OFF.
7. USE FLASHING WARNING LIGHTS WHEN OPERATING ON HIGHWAYS EXCEPT WHEN PROHIBITED BY LAW.
8. MAKE CERTAIN EVERYONE IS CLEAR OF MACHINE BEFORE STARTING ENGINE OR OPERATION.

FIGURE 40. TYPICAL WARNING SIGN
FOR POWER DRIVEN EQUIPMENT.

G. Operator's Manuals. The operator's manuals provide another source of information for the tractor operator. They are designed to educate the user in the functional use, arrangement, adjustment and servicing of the mechanical components and to instruct him in the safe and proper operation of the equipment. These manuals of the major manufacturers are well written and well illustrated. The consensus of university personnel concerned with operator elements of tractor safety, however, is that too few tractor operators bother to read the manuals in sufficient detail.

4.4.3 Bases for Current Operator Training Programs and Program Materials

The design and content of current tractor operator training programs have been based on technical opinion and on reviews of the literature, including reports of tractor accidents. An important input to tractor operator training programs resulted from a study sponsored by the National Safety Council's Farm Conference. (83). The majority of the 172 tractor accidents analyzed in this study, most of them fatal, occurred during the years 1962-1966. One hundred of the cases involved tractor overturn. The remaining cases dealt with a variety of other types, including falls from and runover, pedestrian runover, power take-off, collision with motor vehicles,and fire.

For each case, the recommended operating practice(s) was recorded that was considered most likely to have been able to prevent that particular accident if followed. A change in equipment or addition to the machine was also listed that was considered most likely to have been able to prevent that particular accident had the change or addition been used. Also, a judgment was made on each case on tractor operator or victim deficiency(ies). The deficiencies were classified as: (1) knowledge, (2) alertness, (3) foresight, (4) judgment, and (5) skill. This breakdown is used in the National Safety Council's Defensive Driving Course as elements of defensive driving.

As a result of this analysis of 172 tractor accidents, the investigators identified the following operating practices which, if followed, they felt would have reduced accidents. In this list, the rules are listed in order of decreasing importance.

- Stay clear of ditches, embankments, holes.
- Don't permit others to ride.
- Keep children off and away.
- Slow when turning, crossing slopes and on rough, slippery, or muddy ground and roads.
- Watch for, avoid obstacles.
- Stay off hills and slopes too steep for safe operation.

- When stopped, take tractor out of gear, set brakes firmly, or use park lock.
- Do not overload tractor. Engage transmission clutch slowly.
- Watch where you are going, especially at row ends, on roads, around trees...
- Be fit and ready to drive safely today. Make sure anyone who operates a tractor is also trained, fit, ready and experienced in the particular job.
- Set wheels as wide as practical for the job.
- Operate tractor smoothly -- no jerky turns, starts, stops.
- Be sure everyone is clear before moving.
- Hitch only to drawbar, specified hitch points, or in the case of draft links drawbar, pull with lower links level or below.
- Lower loader bucket when traveling and before dismounting.
- Keep PTO shields in place.
- Use lower gear up and down hills.
- Stop PTO, shut off engine before unclogging, cleaning, or adjusting machines.
- Take extra care not to lose your balance when standing while driving.*
- Stop, look before entering or crossing roads. Obey traffic rules. Signal turns.
- Run and maintain tractor according to operator's manual.

*The writers of this report could not identify any operation that required the operator to stand. Accordingly, because of the unstable position of a standee in a moving vehicle, this practice is not recommended. Moreover, with the advent of the tractor cab and other operator protective devices, it is difficult if not impossible for the operator to stand while in the operator's compartment.

- Never block wheels when stuck. Try to back out. Engage clutch gently. If you can't pull out safely, get help.

- Refuel only when engine is cool. Don't spill gas. No smoking.

- Drinking and farm tractor driving don't mix.

- Don't operate a hand clutch from the ground.

- Add front or rear weight to properly balance tractor.

- Release brakes before starting.

- Stop tractor motion before dismounting.

An additional result of the study reported by the National Safety Council was the identification of operating practices which, if followed, would minimize the frequency of tractor upsets. (83). Since all of these operating practices are included in the above listing, they are not repeated here.

Another excellent source of information for use in training programs are the case studies developed by the Institute of Agricultural Medicine, The University of Iowa, Oakdale, Iowa, under a grant from the U.S. Public Health Service. For the past four years, this Institute has conducted epidemiologic investigations of burns, fractures and amputations. Agricultural tractors were the agent in many of the cases investigated. The information developed by these investigators represented one of the few bodies of "hard" data available to date and should be widely disseminated.

4.4.4 Deficiencies Noted in Current Tractor Operator Training Programs

Significant deficiencies exist in several tractor operator training programs. The more important of these are as follows:

A. Failure to point up the characteristics of the equipment to the extent believed necessary. Donaldson states, for example:

> ". . . The most serious omission from safety programs is information concerning the nature and reactions of the farm machine. Rarely does anybody tell the farmer of the limitations or the inadequacies of his machine. Accordingly, he does not comprehend the dangers and therefore does nothing to avoid them. In many cases a real awareness of the problem is noticeably lacking among farmers . . . ." (23:56).

B. Failure to provide for discussion and demonstration of selected emergency type situations and the performance required either to avoid the situation or minimize its consequences. A finding that tends to support this contention was the observation of Willsey and Liljedahl who, upon interviewing 145 victims of non-fatal tractor overturns in Indiana, found that in only 20.7 percent of the accidents did the operator recall making a last-minute attempt to prevent the overturn. (193:9).

At Purdue University, in a study being sponsored by the U.S. Public Health Service, a ride simulator has been built to study the reaction time of tractor operators using several types of manual controls for emergency conditions such as approaching an overturn condition. (164). The overall objective of this investigation is to improve the method of controlling off-highway tractors as they approach unstable conditions. The specific aims of the research are:

1) To classify the conditions existing just prior to overturning for a representative sample of tractor accidents.

2) To determine the dynamic behavior of tractors as they approach instability and to identify those signals which can be used to warn the driver and which may also be used as input signals for an automated control system.

3) To study the motor reflexes of tractor operators as instability is approached with special reference to the time of response, in using the primary controls of the tractor.

4) To study and design promising improved warning systems, manual and automatic controls which may reduce the probability of a tractor overturning as it approaches an unstable condition.

The results of this research may provide valuable input for future tractor operator training programs.

C. Lack of attention to the post-crash (loss limiting) phase of the tractor crash. Following are some examples of information that the operator should know and skills he should be able to perform in order to control the extent of loss following a tractor crash:

1. Orient himself to the post-crash situation.

2. Make an accurate assessment of the crash situation. (Here, a card or decal containing step-by-step procedure to be followed after a crash, carried in the passenger compartment, is recommended.)

3. Extricate himself from tractor or tractor-implement combination in such a way that no additional injury to himself or to others, or additional damage to equipment, results.

4. If conscious, but unable to evacuate the vehicle, instruct others in how to extricate him from the vehicle.

5. Prevent fire during post-crash situation.

6. Extinguish or otherwise control fire during post-crash situation.

7. Call for assistance, if required.

8. Provide essential information to source(s) from which assistance was requested.

9. Administer first aid.

10. Secure or assist in securing the crash site (take actions designed to reduce the probability of additional crashes [if crash occurred on roadway], and take actions to maintain integrity of crash site).

11. Provide accurate input to investigator(s).

12. In the absence of investigator(s), record routine information relating to the crash in an accurate, objective manner.

D. Insufficient attention to actual and to potential injury and health hazards associated with tractor operation, and to the operating procedures and protective clothing and equipment that is available to eliminate or minimize these hazards. Among the hazards that are not treated in significant detail in current training programs are: heat and cold injuries; hearing loss; inhalation of dusts, sprays, and toxic fumes; and injuries associated with the vibration levels of some equipment. In addition to the redesign possibilities suggested by some of these hazards to health, protective clothing and equipment worn by personnel in the manufacturing and construction industries is indicated for the tractor operator; e.g., hard hats, safety glasses, respirators (when working with sprays and fertilizers), and hard-toed shoes. Tractor operators may want to consider wearing light weight vests with retro-reflective material of the type worn by highway construction workers and by traffic patrolmen. This is especially important when operating the tractor off the farm.

One of the more encouraging activities noted in several areas of the country were the programs to encourage members of farm populations to have their hearing checked, and the promotion of the sale of ear protection. Reportedly, the sale of ear protection is going well and users are pleased with the noise attenuation qualities of these devices.

E. Lack of consumer information. Current tractor operator training programs provide little in the way of consumer information. While it is acknowledged that such information is sparse, little of that which is available is included in current programs. One example of source data is the publication Nebraska Tractor Test Data. (178) There is also a need to acquaint the consumer with the results of tests involving tractor overturns with rollbars and cabs which have roll protection. Relevant to this, Poyner points up the role of education in convincing the farmer as to the value of overturn protection and seat belts as follows:

> "We are convinced that tractor protective frames do contribute to operator safety in the event of overturn, particularly if his seat belt is properly fastened. However, it is a matter of record that farmers are not flocking to the dealer's store to purchase these frames. It will take long and continuous promotion on the part of the industry and all safety groups involved to put this program into widespread application."(121:7).

F. Part-time instructors. With the exception of those training programs conducted for vocational agriculture students, all other training programs rely on volunteer help for instructors. Some States report difficulty in getting adequate numbers of qualified personnel to provide instruction for prospective tractor operators who are not enrolled in vocational agriculture programs. Marvin (Appendix A:A196) cities reliance on volunteer help as one of the limitations of current 4-H Tractor Care and Safety Programs.

G. Training programs for instructors. There is a marked absence of training programs for those who instruct tractor operator trainees. It is especially important that anyone instructing youth in tractor operation be familiar with the principles of effective instruction and how these principles are applied.

H. Lack of a built-in evaluation plan for current tractor operator training programs beyond those which are represented by the tests of student trainee knowledge and skill. The U.S. Department of Labor has requested the U.S. Department of Health, Education, and Welfare and the U.S. Department of Agriculture to provide information on injuries to youth who received exemptions to the Hazardous Occupations in Agriculture Order by completing a training program which had been approved by the U.S. Department of Labor's Bureau of Labor Standards.

The long-term evaluation of tractor operator training programs eventually must come to grips with the "real-world" of tractor operator performance and with the social costs associated with operating a tractor both on and off the farm. Thorndike, in commenting on accidents in general in relation to the program of instruction received by the victims, makes this observation:

> "One criterion in terms of which any training program might be appraised is the subsequent accident rate of those who went through the particular routine of training. However, the assembly of satisfactory data for such a comparison tends to be a major enterprise. Particularly where accidents are rather rare occurences, the accumulation of data proceeds slowly and there is a substantial lapse of time before individuals have been trained by the methods under comparison in sufficient numbers and followed up through a sufficient period to permit the assembly of adequate records." (171:116).

4.4.5 Guidelines for Developing Training Programs for Tractor Operators and for Those Who Conduct These Programs

A training program should be developed only after a thorough analysis has been conducted of the tasks which the tractor operator is required to perform. The analysis of these tasks should be followed by descriptions of performance which can be used as bases for identifying course content of initial, refresher and remedial training programs. These descriptions of performance should be capable of being translated into standardized, objective, quantifiable proficiency measures which can be used as one basis for evaluating the effectiveness of training programs. Also, the training programs should focus on the most critical of the tasks which the tractor operator performs, since it probably will not be possible to teach all of them.

Crawford (140) reports on a general schema (Figure 41) for designing relevant training that has evolved over 17 years of research and development for the U.S. Army and others by The George Washington University's Human Resources Research Office (HumRRO)*. Guided by this schema, successful training programs have been developed for a wide variety of occupation specialties, ranging from technical jobs to positions of supervision and leadership. Crawford reports that the use of this approach has shortened training time, lowered costs and improved on-the-job proficiency. Several additional models of and for training have been developed and reported in the literature. (55).

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*Effective September 1, 1969, HumRRO began operations as an independent non-profit research organization.

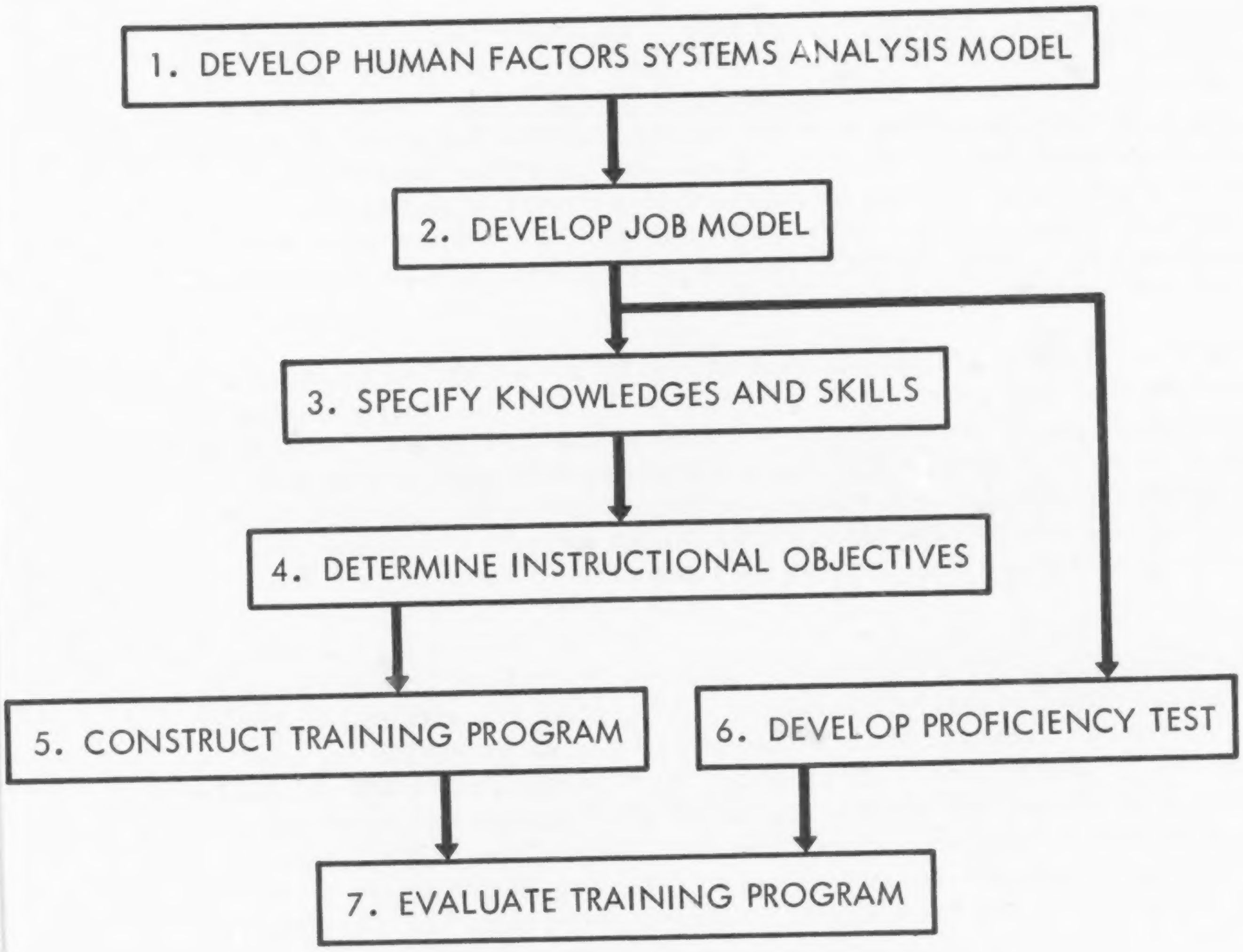

1. DEVELOP HUMAN FACTORS SYSTEMS ANALYSIS MODEL
2. DEVELOP JOB MODEL
3. SPECIFY KNOWLEDGES AND SKILLS
4. DETERMINE INSTRUCTIONAL OBJECTIVES
5. CONSTRUCT TRAINING PROGRAM
6. DEVELOP PROFICIENCY TEST
7. EVALUATE TRAINING PROGRAM

FIGURE 41 - TRAINING SCHEMA

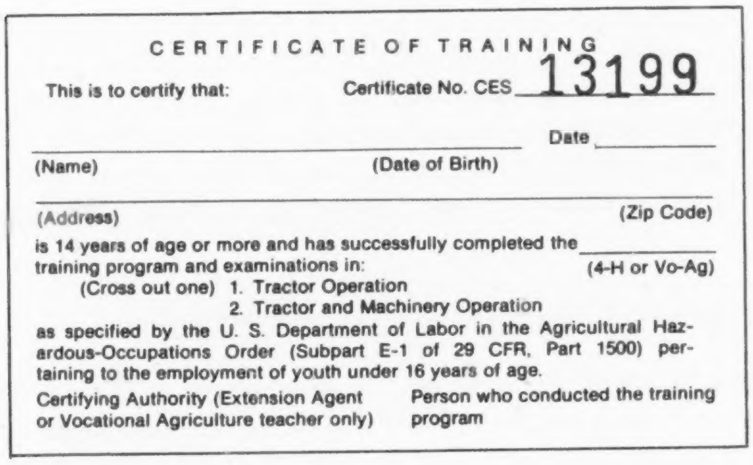
4.5 Operator Certification. Currently, no State requires tractor operators to be certified in the sense that operators of motor vehicles are required to be licensed. The Uniform Vehicle Code would require a driver's license for operating a farm tractor on the highway; however, the laws of most States do not. Until the interim Hazardous Occupations in Agriculture Order, designed to protect hired farm workers under 16 years of age from particularly hazardous jobs was published in January, 1968, little attention was given to qualification standards for tractor operators.

The Fair Labor Standards Act of 1938, as amended (January 7, 1970), states that the provisions of Section 12 (of the Act) relating to child labor shall apply to an employee below the age of 16, employed in agriculture in an occupation that the Secretary of Labor finds and declares to be particularly hazardous, among which is the operation of a tractor of over 20 power takeoff (PTO) horsepower, or connecting or disconnecting an implement or any of its parts to or from such a tractor.

The Certificate of Training is uniform for all of those 14- and 15-year olds who satisfactorily complete a program of instruction in Tractor Operation or Tractor and Machinery Operation which is approved by the U.S. Department of Labor. The certificates are serially numbered and each State maintains a record of students who complete the training and who are issued certificates. This data will assist researchers in their efforts to associate tractor accident types with the type and recency of the training the victim received. A copy of the Certificate of Training is reproduced at Figure 42.

4.6 Non-Operator Victims of Tractor Crashes. Little is known of the non-operator victims of tractor crashes. In the National Safety Council study of 789 tractor fatalities, of the 624 cases (79 percent) on which information on the status of the victim was obtained, 4 percent were passengers on the tractor, 7 percent were pedestrians, and 1 percent were occupants of towed vehicles or implements. Another 8 percent were occupants of the tractor, but the data recorded did not indicate whether these victims were drivers or passengers. (105:7). There is no indication whether the "pedestrian" classification included persons working in the vicinity of the tractor at the time of the mishap or whether all were pedestrians on a roadway. An analysis of 212 fatal and 7,000 injury-producing but non-fatal accidents involving tractors in Ohio during the period 1956-1960 revealed that 28 of the 29 tractor passengers (other than the operator) who were killed were under 16. (79:11). The authors of the Ohio study make this statement:

> " From the design viewpoint, the question arises whether it is better to attempt to design a tractor to discourage extra riders, or to accept the fact that some will ride anyhow and design a safe place for them to ride." (79:11).



CERTIFICATE OF TRAINING

This is to certify that: Certificate No. CES 13199

______________________ Date ________

(Name) (Date of Birth)

____

(Address) (Zip Code)

is 14 years of age or more and has successfully completed the ________ training program and examinations in: (4-H or Vo-Ag)

(Cross out one) 1. Tractor Operation
2. Tractor and Machinery Operation

as specified by the U. S. Department of Labor in the Agricultural Hazardous-Occupations Order (Subpart E-1 of 29 CFR, Part 1500) pertaining to the employment of youth under 16 years of age.

Certifying Authority (Extension Agent or Vocational Agriculture teacher only)

Person who conducted the training program

FIGURE 42, CERTIFICATE OF TRAINING

In discussions with members of the staffs of agricultural engineering departments of several of this nation's land-grant universities, the consensus was that there is no reason for anyone other than the operator to be on a tractor when it is in motion. These individuals tended to favor the approach of designing a tractor that would make it virtually impossible for anyone but the operator to ride. Poyner of the International Harvester Company has this to say about more than one passenger on a tractor:

> ". . . critics say we should provide room for more than one person to ride on a tractor. While this is done in some European countries where a tractor sometimes serves also as a mode of highway transportation in place of the automobile, we feel that the operator's platform of our modern day tractor has room for only one good comfortable bucket seat with leg room and platform clearance for comfort and operator controls necessary for freedom of movement. It should not be used as a vehicle to transport people." (121:13).

All university personnel contacted during the study stressed the importance of educating both the youth and adult populations to the hazards of riding on a tractor as a passenger and to avoid coming into close proximity with a tractor when it is in motion. All of the tractor operator training programs reviewed during the preparation of this report stressed the importance of not permitting anyone other than the operator on the tractor.

4.7 The Crash Phase of the Crash Event

During the tractor crash, there is little that the operator can do. To reduce the probability of death, injury or property damage once the crash has started to occur, it is necessary that the operator have taken actions prior to this time to attenuate the forces between him and the tractor, or other objects if he is ejected from the tractor. Payoff comes from overturn protection for the tractor, laminated glass (in the case of a cab), seat belt, hard hat, and other protective features. The role of education or training during the actual crash is nil.

4.8 The Post-crash Phase of the Crash Event

During the post-crash phase, the objective is to minimize the loss to the victim and to property involved in the crash. Insofar as the tractor crash victim personally is concerned, his survival will depend upon advance preparation (e.g., overturn protection system for the tractor and personal protective equipment, and training in post-crash procedures), and how well the nearest community is prepared to cope with such emergencies (e.g., availability and quality of emergency medical services). Other important activities associated with the post-crash phase relate to the application of the knowledge and skills that were taught to the operator during his training.

4.9 Concluding Statement

It is not possible now to develop a precise description of the role of the human element in the man-machine-environment interface of agricultural tractor operation. An extensive research effort is required to provide information on operator characteristics to manufacturers of tractors and implements, to those who work in professional agriculture occupations, to public and private groups working in support of improved safety on the farm, and to the farm population. A farm accident reporting system of the type described in a later section of this report will provide a base for much of this research. In the meanwhile, there is a need to apply the results of the valid research that has been reported, much of which is referenced in this report.

CHAPTER FIVE

5.0 Environmental Considerations

The tractor is used by the farmer both on the farm and on the public road. The nature of the tractor use, however, differs considerably in these two environments.

On the farm, the tractor acts as a stationary power source, providing power to auxiliary equipment. It also acts as a dynamic power plant, providing mobility to machinery at the same time serving as an operating force. On the road, the tractor is used to move auxiliary equipment from one place to another as well as to transport farm products. It is also used to transport persons. Thus, it is a machine which has multifunctional uses in daily farm operations.

The multifunctional nature of the tractor suggests that few environmental constraints are placed on its use. The tractor has a seemingly all-purpose capability to operate over almost any terrain in any kind of weather, or to perform any power-related task, given the proper accessories.

As Knapp and Hindman have stated:

> "Man and machine are brought together in an environmental situation (farmstead, road, field, etc.) . . . where accident situations are propagated. This segment represents the application of the farm tractor to various tasks considered practical and appropriate by the user in his farming operations. 'Practical farm use' is the utilization of the tractor from the customary work of pulling tillage tools to pushing autos out of ditches, positioning elevators, chasing cows, and transporting people. It [the tractor] serves as a power source for innumerable devices supposedly designed to make farming easier and often ordered from a catalog. In many instances, these additions to the tractor create real safety hazards because they radically change the stability of the tractor. Such changes are not apparent to the user, for he is unaware of the intent of tractor design and unprepared to cope with unexpected tractor reactions.

> "The reaction of a machine to a changing job situation is not automatic, and the whole burden of corrective action rests upon man's varying physical and mental limits. His actions are further subjected to such stresses as may be placed upon him by the machine he is operating. In addition, the operator is faced with the environmental factors of weather and terrain, which are constantly changing, even while the meeting of man and machine is taking place." (70:36).

5.1 The Farm Environment

Farming is a basic industry related to soil tillage and crop production. In its multifunctional use, the tractor is operated in almost any kind of farm environment and under almost any combination of environmental elements. Yet when farm tractor accidents occur, very little hard data is recorded on the status of particular environmental elements as they exist during the pre-crash, crash and post-crash phases of the accident. Few reports of such accidents or of studies of accident causation attempt to define in any precise manner the role of the environment in the machine-man-environment interface relationships.

The status quo of information most generally available on tractor accidents is exemplified in a report by the National Safety Council on "Tractor Fatalities -- Characteristics of 789 Cases." (105). This study of fatalities occurring in 13 States between 1960 and 1965 provides statistical data gleaned primarily from death certificates or summaries and from newspaper clippings, tabulated in such manner as to provide answers to about 45 questions concerning circumstances of the accidents. The availability of information relating particularly to environmental conditions may be summarized as follows:

Percent Providing Answer	Nature of Question
* [1]	Weather
*	Ground condition
3	Road surface
1	Temperature
2	Character of immediate terrain

---

[1] Less than one-half of one percent answered question.

Percent Providing Answer	Nature of Question (Cont'd)
7	Tractor motion
*	Overturn protection
*	Person whose vision was obscured
*	Vision obscured by
44	Month of accident
44	Day of week
25	Hour of day
26	Light condition
17	Surface hazards
36	Tractor use
3	Tractor type
35	How soon medical attention obtained
43	Time elapsed between injury and death
86	Place of accident (farm property -- 70 percent; other -- 30 percent)

Thus it may seem that on the basis of present information it is not possible to make more than superficial judgments on the environmental factors involved in tractor accidents, injuries and deaths. A farm accident reporting system should be designed to provide a proper research base for a better understanding of this aspect of the tractor accident safety problem.

5.2 Countermeasures for Farm Environmental Conditions

Only limited countermeasures directly related to the farm environment have been developed or recommended. The environment is relatively fixed so that countermeasures are applied primarily to tractor design and tractor use. Overturn protective equipment and other tractor safety devices are designed to lessen the chances of overturn on embankments and steep hillsides, or as a result of surface holes and obstacles. Cabs and canopies help protect the operator from heat, cold, and excessive exposure to the sun. It is understood, however, that the latter elements of the environment are fixed for the farmer, hence accommodation to,rather than change of, the elements of nature is necessary.

Within the bounds of farming operations, certain adjustments of environment are possible. Drainage tile and alterations of drainage patterns do alter surface conditions; ditches may be covered over, holes filled and obstacles removed. Steep slopes may be returned to natural pasture or forest area.

For the most part, however, adjustments in tractor safey are made by applying countermeasures to the man-made environment and only indirectly to the environment of nature. The assumption is implicit, both in tractor design for greater safety and in operator training for safe driving, that the environmental element of the man-machine-environment complex is unforgiving and only relatively giving. For this reason, then, the countermeasures aimed at critical elements of the farming environment are included in the sections of this report that relate to overturn and power takeoff accidents and operator-caused accidents.

5.3 The Highway Environment

With the introduction of rubber tires for tractors in the late 1920's, it became feasible to operate these vehicles on improved roads, thereby adding a new dimension to both the tractor and the highway safety problem.

As farming operations changed with the rapid growth of labor-saving machinery, individual farming operations expanded and encompassed more land, often by the addition of non-contiguous land parcels. Thus, the need to operate tractors on the public road increased. In a study recently performed in Michigan, for example, it was noted that of those farmers surveyed, 40 percent drive slow moving vehicles (SMV) on the highway at least once a week and only 15 percent had no occasion to drive tractors or self-propelled machinery on the highway.

Farm tractors and self-propelled farm machinery are limited as to their operating speed. Few if any of these vehicles are designed to attain or exceed an operating speed over 20 mph. When trailing loaded wagons or other auxiliary equipment, their safe operating speed is even lower. Tractors and equipment similar in character (construction equipment, highway maintenance equipment, animal drawn vehicles) have been termed SMVs as their designed operating speeds are considerably lower than those of most passenger cars, trucks and buses. Farm tractors operate predominantly in a rural environment where many highways are constructed to permit high speed travel. Therefore, a speed differential exists between the motor vehicle designed for high speed travel and operating over a roadway constructed to accommodate such travel, and the SMV which is required to use the public road for certain purposes.

Today, according to National Safety Council estimates, approximately 25 percent of fatal tractor accidents occur on the highway, nearly half of which involve a motor vehicle. On a regional basis, studies performed in North Carolina indicate that approximately 30 percent of tractor related fatalities occur on the highway, 40 percent of which involve a motor vehicle. For Iowa, approximately 32 percent of such fatalities occur on the highway, while only 27 percent involve a motor vehicle; for Ohio, approximately 20 percent occur on the highway, no figures are available concerning motor vehicle involvement.

Thus highway accidents constitute a significant part of the farm tractor accident problem and must receive attention by those concerned with farm safety programs. Even though the problem of tractor safety is primarily one related to farm operations, use of public roads by tractors as slow moving vehicles creates a matter of concern to automobile drivers.

Information gathered from police sources has been utilized by researchers to classify those accidents where the easily distinguishable slow moving vehicle has been directly struck in the accident as to type and severity, and to note the status of certain environmental factors pertaining to the event. Certain problems with respect to these accidents are evident and are reviewed below.

5.4 Characteristics of Tractor Related Highway Accidents

Information from studies conducted in several States has been reviewed with regard to type of accident, type of collision, type of road and road surface, road character and location, light condition and vehicle speed. (126) (159) (186). The following areas were found to be significant with regard to tractor related highway accidents:

- The single vehicle accident, involving only the farmer and his slow moving vehicle, was indicated to be a substantial source of fatal farm tractor highway accidents in certain regions of the country (Iowa and North Carolina). Although these accidents occurred infrequently (approximately 10 - 15 percent), they accounted for a high number of the fatalities (approximately 60 - 75 percent).

- Collisions between farm tractors and other motor vehicles were the most frequent type of accident (Iowa approximately 85 percent, North Carolina 89 percent, and Ohio 96 percent of tractor accidents on public roads).

- "Same direction of travel" collisions, where both vehicles were going straight ahead and traveling in the same direction, were the most frequent type of collision between farm tractors and other motor vehicles (59 percent of the accidents in North Carolina). A majority of these involved both vehicles going straight (82 percent) and generally resulted in rear end collisions. In nearly all of the remainder, the motor vehicle was attempting to pass the tractor and a sideswipe collision resulted.

- Rear end collisions in North Carolina occurred with almost equal frequency during daylight (180 cases) and other light conditions (176 cases). It was also noted that this type of collision constituted a majority of the accidents which occurred during the dawn, dusk, and darkness (176 of 242 cases) while rear end collisions were a less significant portion of the daylight accidents (180 of 631 cases). Poor rear lighting was indicated as a defect in a majority of nighttime accidents (122 of 147 cases). No insight as to contributing influence was offered for those rearend accidents that occured during daylight.

- The largest accident category of SMV accidents in Ohio consisted of rear end collisions on open highways. Approximately 90 percent of all collisions occurred during daylight hours on dry highways--free of rain, snow and ice. Also, motor vehicle operators reported their view of the slow moving vehicle was obstructed by hills in only 6 percent of the collisions, and by another motor vehicle traveling between them in 2 percent of the collisions.

- "Turning maneuver" collisions, where the tractor was entering or leaving the highway, or those where the tractor was turning left and the other vehicle was going straight, accounted for a significant portion of the accidents (33 percent) reported in North Carolina. A majority of these collisions occurred during daylight. (North Carolina and Ohio data indicate that where SMV turning movements resulted in a collision, in a majority of the cases the slow moving vehicle was turning left.)

Based upon this type of data, countermeasure programs for the SMV problem were developed. Major efforts to date have included: (1) providing adequate illumination and pre-warning systems so that motor vehicle operators can recognize SMVs and speed differential characteristics; (2) educating farm equipment operators and the motor vehicle public as to driving procedures when these vehicles are part of the traffic stream; (3) providing mirrors to increase the operator's field of view and turn signals for display of planned maneuvers; (4) providing protection against injury in case of an accident (e. g., overturn protection, discussed in Chapter 3).

Equipment countermeasures developed or recommended in the areas of improving driver performance, their degree of implementation and measured effectiveness are described in succeeding sections of this report.

5.5 Countermeasures for Tractor-Related Highway Accidents

5.5.1 Headlights for Tractors

In a recent review of State laws requiring lights, reflectors and emblems on farm tractors and implements of husbandry, the National Committee on Uniform Traffic Laws and Ordinances makes the following comment:

> "Headlights are lighting devices with a primary function of illuminating the highway in front of the vehicle so that the driver can see far enough ahead to drive safely. The distance for which headlights should be required to illuminate the highway in front of the vehicle is, to a substantial extent, a function of the speed of that vehicle. Because farm tractors travel at relatively slow speeds, headlights having illuminating powers equivalent to those used on high speed vehicles generally would not be necessary. However, a secondary function of headlights is to make the vehicle more visible to the drivers of vehicles approaching from the front, and, to some extent, those approaching from the rear. Because increased visibility appears to be an important factor in decreasing accidents involving slow moving vehicles, the use of headlights with greater illuminating power than required by the speed of the vehicle probably should be encouraged on farm tractors and implements of husbandry.
>
> "The Uniform Vehicle Code requires all farm tractors and self-propelled implements of husbandry operated at night to have at least two headlights. The Code no longer required front lights on self-propelled farm vehicles nor on the left side of any combination of farm vehicles. [A front light has been defined by the Committee as any lamp, other than a headlamp, that emits a light visible from in front of a farm vehicle. Its primary purpose is to notify other traffic of the presence of a farm vehicle . . . Front lights are also frequently required by State laws to be positioned so as to indicate the extreme left projection of a farm vehicle or combination. The Code also requires that headlamps for farm vehicles must meet or exceed minimum performance standards in providing illumination for a specified distance.] The laws of 34 States

> require headlights on some or all farm vehicles . . . . The laws of 40 jurisdictions require front lights on some or all farm vehicles. . . ." (95:1).

The Committee reviewed specific State legislation regarding headlamps, The information indicates that there is a wide variation between the States as to types of forward lighting required on the tractor or self-propelled farm implement. Some of the findings follow:

- Certain States (11) require headlights on all farm tractors and self-propelled farm implements. Other States (3) do not exempt such tractors and farm implements from motor vehicle lighting requirements, and as a result such vehicles must be equipped with headlights as required for motor vehicles generally.

- Certain States (9) require headlights on all farm tractors and self-propelled farm implements which are equipped with an electrical lighting system, and a front light on all such vehicles which are not equipped with an electrical lighting system.

- Certain States (6) require headlights only on farm tractors (but not on other self-propelled farm implements) which are equipped with an electrical lighting system.

- Certain States (6) require headlights on self-propelled farm implements, but not on farm tractors.

- Certain States require front lamps and specify positioning, others do not specify positioning. "Depending on the type of lamp, or the beam emitted by the lamp, the distance specified ranges from a low of 50 feet in one State to 500 feet in two States." (95:4).

5.5.2 Taillights and Reflectors for Tractors

The National Committee on Uniform Traffic Laws and Ordinances has established Codes for the use of tail lights and reflectors on tractors, self-propelled farm implements, and combinations of tractor and towed implements.They note that the Uniform Vehicle Code "requires all farm tractors and self-propelled implements of husbandry to be equipped with at least one red taillamp, visible when lighted from 1000 feet to the rear, and with two red reflectors, visible when illuminated by lower beams of headlights at all distances between 600 and 100 feet." (95:4).

For combinations of farm tractor and towed implements the Code:

> " . . . requires the towed vehicle to be equipped with two red reflectors if it extends more than four feet to the rear of the tractor or if it obscures any lighting devices on the tractor. These reflectors must be mounted to indicate both the extreme right and left projections of the vehicle. Whenever the towed unit extends more than four feet to the left of the centerline of the tractor, the towed unit must be equipped with one amber front reflector, mounted to indicate the extreme left projection of the towed unit. All reflectors required on the towed unit must be visible when illuminated by lower-beam headlights at all distances between 600 and 100 feet." (95:6).

The Committee describes the wide variation between States as to markings required for the rear of the tractor, self-propelled implements, and combinations of tractor and towed implements (95:7):

- Only one State has a law conforming in all respects with the Uniform Vehicle Code (with respect to taillights and reflectors).
- Certain States (12) probably are in substantial agreement with the Code with respect to rear lighting on farm tractors and self-propelled implements.
- Certain States (9) require one light and two reflectors but not on all such vehicles.
- Certain States (23) require one light but no reflector on the rear of all farm tractors and self-propelled implements.

5.5.3 Slow Moving Vehicle Designation

There appears to be a consensus among farm safety experts that an adequate method should be developed to permit positive recognition of a SMV by the motorist at a safe distance to permit proper speed differential adjustment. In a research effort by Stuckey and Harkness at The Ohio State University, the following was reported:

> " . . . MV-SMV [motor vehicle-slow moving vehicle] collisions are a 24 hour per day, 365 days per year problem. They occur mostly on good, open highways, during daylight, nice weather, and without the motorist's view being obstructed. Rear end collisions predominate, and account for most of the fatalities, injuries and property damage.

> ". . . . The product of this research was a unique, triangular emblem, designed to help MV operators recognize a SMV in time to act appropriately and avoid a rearend collision. Once this triangular SMV emblem comes into wide usage it will communicate to motorists the lurking danger through unique color and shape recognition -- just as we now recognize a railroad crossing by the familiar 'cross-buck.' Research has shown the base down triangle of fluorescent orange surrounded by reflective red to be one of the most recognizable combinations of shape and color. It has been designed to be distinguishable at a distance of 1/6 of a mile back from the SMV. (None of the flags, reflectors, or lights currently employed to mark SMV's constitute a uniqueness that will effectively alert a motorist under both daytime and night driving conditions. These devices are used so diversely that they do not distinctly communicate any specific danger.)
>
> "The emblem is intended for use with safety devices required by law. In addition to the emblem, for night travel at least one continuous red tail light is recommended on the rear of a SMV, preferably two. The red lights are visible for long distances at night and as a motorist approaches the SMV, headlamps illuminate the emblem, thereby telling him what the red lights represent. The red lights alert, the emblem communicates.
>
> "The SMV emblem has been field tested from coast to coast. Several major farm machinery manufacturers have extensively tested the effectiveness of the device. The Institute of Agricultural Medicine at the State University of Iowa and the Cooperative Extension Service of Purdue University have conducted field trials also. All of these studies substantiate the results of The Ohio State University research." (159:2).

It is noted that the Farm Conference of the National Safety Council and the American Farm Bureau Federation (Appendix A:A241) support the use of the SMV emblem. Further, the American Society of Agricultural Engineers has established recommendations covering fabrication and use of the emblem.

In a separate effort at Iowa State University, various warning devices, developed to alert the motorist to SMV's on the road, were tested as a part of a study of accidents of farm tractors. The results were published in a report entitled "Testing Motorist Identification of

Slow Moving Vehicles on Public Roads," which may be summarized as follows:

> "These tests were an attempt to measure the comparative warning effectiveness of various devices including the tractor itself. The tests were conducted on public highways with moderate traffic in four areas of the State. The effectiveness at any time on a public road may be less than that found here because of heavier traffic, weather or other adverse conditions. It is doubtful if any device would do better than here reported except for a few people under ideal conditions."
>
> "A rating formula was developed to comparatively evaluate the various devices. The percentage of motorists seeing the device at various distances was the basis of the formula." (188:16).The results of the test are shown in Table 11.

TABLE 11
DISTANCES MOTORISTS SEE SMV AND WARNINGS

	Tests	Under 50'	Over 250'	Over 500'	Rating
Fluorescent Flag	34	76. 4	14. 7	8. 8	0. 0
Flashing Red Light	72	22. 4	65. 7	58. 4	55. 0
SMV Emblem	797	17. 6	71. 1	57. 3	64. 8
Steady Amber Light	210	16. 6	69. 5	50. 5	64. 9
Tractor	495	6. 1	79. 6	59. 8	86. 6
Red & White Flag	41	4. 9	85. 4	70. 7	92. 4
Rotating Amber Light	52	3. 8	90. 4	78. 8	97. 4
Flashing Amber Light	68	1. 5	86. 7	76. 5	98. 8

(Source: 188).

> "It was rather amazing how good the tractor served as its own warning device. Only three devices did better. The stationary amber light was not very effective. A flasher in the light made it far more effective.
>
> "The red and white striped flag was very effective. However, for one short period it was very poor. When it rained, it was never seen. The flag also has an

> insurmountable problem of maintenance. Considering all factors, it is simply not a good warning device. In Iowa from 1949 to 1966, over 200,000 warning flags were sold to farmers. Practically none can be found today. "
>
> " The SMV Emblem showed up poorly as a warning device. However, it was developed for identification, not warning. That is why we now recommend the flashing amber light to warn and the SMV emblem for identification." (188:17).

The National Committee on Uniform Traffic Laws and Ordinances has established Codes with respect to implements of husbandry traveling on the public highway. The 1968 Revised Uniform Vehicle Code called for " . . . every farm tractor and self-propelled implement of husbandry to be equipped with vehicle hazard warning lights (four-way flashers) which must be displayed whenever the vehicle is on the highway. These simultaneously-flashing lights must be visible, red or amber to the rear and white or amber to the front, from 1,000 feet in normal sunlight. These flashing lights are required irrespective of the time of day." A further provision has been to require the slow moving vehicle emblem" . . . on all farm vehicles and combinations that operate at speeds under 25 miles per hour. The emblem would be visible to the rear and would be required whenever farm vehicles are operated on the highway." (95:7).

The Committee notes that to date (10/5/70), "Only one State requires simultaneously-flashing vehicle hazard warning lights on all farm tractors and self-propelled implements of husbandry. Only two other States require any flashing lights on farm tractors or implements of husbandry. One State ". . . requires either the slow moving vehicle emblem or an amber flashing light . Four additional States . . . expressly permit the use of flashing lights on certain farm vehicles but they do not require it." (95:7)

With respect to the slow moving vehicle emblem, "Sixteen [States] require the use of the emblem on certain vehicles under some or all conditions . . . four States have laws which merely permit the use of the emblem" (95:8).

5.5.4 Tractor Turn Signals

A study by Roberts and Suggs at North Carolina State University indicates a need for tractor turn signals. The study notes:

> " It is also strongly believed that a requirement for turning signals on tractors could lead to a measurable reduction in the frequency of accidents.

> "Tractors could be equipped with turning signals without much trouble, and little additional cost. There would be some problem providing these signals on trailing implements. However, there should be no problem in developing a portable turn signal system that could be easily connected and disconnected from the tractor lighting system. This could consist of a telescopic tubular system in which the lights could be separated the desired distance and easily mounted to the trailing implement." (126:15).

No information is available concerning the enactment of laws regarding the use of such turn signals for tractors operating on the highway.

5.5.5 Rearview Mirrors

In an investigation of single vehicle tractor accidents, Wardle of the Iowa State University noted:

> "Investigation of many of the non-fatal accidents in these categories revealed that a high percentage of them were the result of the operator looking back. When he looked ahead again, the tractor was near the edge of the road. Acting under the stress of an emergency situation, the operator either acted too quickly and overturned in the roadway, or he acted too slowly and went off the road, perhaps hitting a bridge abutment or other stationary object . . . .
>
> "A tractor actually needs a rearview mirror even more than a car. A good rearview mirror aids the tractor operator in these ways:
>
> 1. He can see behind without turning.
> 2. It provides a wide field of vision.
> 3. He can see all around at the same time and all the time.
> 4. The complete view compensates for the absence of sound warnings obscured by the tractor noises.
> 5. It provides him a valuable assistant in yard and field work by giving him a view of the operating machine." (186:13).

Thirty-seven farmers in 11 States field tested mirrors built to specifications developed at Iowa State University. The vibration problem mentioned in Chapter 3 of this report was the only real criticism, however 100 percent of the farmers recommended that mirrors be used on all tractors.

The number of States is limited which require the use of rearview mirrors for tractors.

5.6 Evaluation of the Effectiveness of Enacted Countermeasures

As noted in the previous section, countermeasure have been developed for use in the prevention of highway tractor accidents. As noted by the National Committee on Uniform Traffic Laws and Ordinances:

> "Significant advancements have been made in the technology of vehicle lighting and they have been reflected in revisions of the Uniform Vehicle Code lighting requirements for farm tractors and implements of husbandry. The Code has consistently required the most effective lighting that is technically and economically feasible.
>
> "Unfortunately, the laws in a great number of States have not kept pace. One-third of the States still require only the minimal lighting devices considered appropriate and feasible in 1926. These States do not require headlights on any farm tractors or implements of husbandry. Another one-third of the States retain distinctions based on an electrical lighting system, even though they were removed from the Uniform Vehicle Code in 1962." (95:10).

As noted above, the States have been slow to adopt new regulations regarding the use of vehicle lighting systems as proposed by the Code. Possibly their reluctance to change existing laws is due to the paucity of information on the effectiveness of various devices to be considered. There appears to be agreement concerning the need for adequate illumination and a method to permit positive recognition of a slow moving vehicle by the motorist. However, there is no agreement as to the complete system that should be adopted.

For example, the Ohio report recommended in addition to use of the SMV emblem, at least one continuous red taillight, preferably two. (159).Wardle recommends the use of the emblem in combination with the flashing amber light. (188). The Uniform Vehicle Code recommends use of the emblem visible to the rear and in combination with a four-way flashing light which must be visible, red or amber to the rear, white or amber to the front, from 1,000 feet in normal sunlight. (95:8).

It is understood that Michigan adopted legislation requiring use of the emblem and retained requirements for front lights only, one taillight and no reflector on the rear of all farm tractors and self-propelled implements, and one light on the rear of all towed implements (without regard to positioning). A later study indicated a significant reduction (47 percent) in non-intersection rear end collisions after the slow moving vehicle law went into effect. (Appendix B:128). This study also noted that little change resulted in the frequency of other than this type of accident (other types accounted for approximately 80 percent of the tractor-related highway accidents in Michigan).

Reports concerning the Michigan experience did not give particulars concerning those non-intersection rear end collisions that did occur, nor information on availability of the emblems. It cannot be determined whether a more effective system was needed or appropriate to the circumstances of the accident; e. g. , 360° positive recognition of the presence of a slow moving vehicle to pre-warn motor vehicle operators approaching these vehicles from all angles.

If turn signals are required for these vehicles, the problem of positioning and distinguishing the signals and the flashing hazard lights must be considered. The effect brake lights would have upon the vehicle lighting configuration also must be assessed.

In summary, it would appear that further research would provide firm guidance as to the appropriate combination of lighting and marking systems for farm equipment. Comparisons could be made of the accident experience between States with varying lighting and marking requirements. All aspects of the SMV problem must be considered before firm recommendations can be made.

If circumstances force immediate corrective measures, it is suggested that the most sophisticated systems available be offered to the SMV user. A method would be to develop a highway safety package for the SMV population. Enabling legislation through the motor vehicle code at the State level is the mechanism recommended to insure incorporation of this "package."

The following items should be considered for incorporation into the package:

- Illumination systems, front and rear, for tractors operating on the highway.
- Rearview mirror systems to permit 360° visibility to the operator.
- Systems to provide 360° positive recognition of the slow moving vehicle by the motorist at a safe distance to permit proper speed differential adjustment both day and night.

- Turn signal systems to provide 360° display of planned operator maneuvers.

The package should be developed to permit retrofit of all tractors operating on the highway since it would take approximately 30 years before such systems could be incorporated on a new vehicle basis.

CHAPTER SIX

6. 0 A Farm Machinery Accident Reporting System

It is specifically noted in section 8(b) of Public Law 91-265 that "In formulating the recommendations to be submitted to the Congress, the Secretary shall give careful consideration to the advisability of. . . providing assistance to the States in developing accurate reporting procedures for accidents involving such [agricultural] tractors."

The above directive is addressed in part toward the resolution of a problem long recognized by authorities in the agricultural safety field. Many of the reports concerned with agricultural safety indicate the need for a farm accident reporting system that would provide continuing scientific data on the extent, nature and causes of farm accidents, resultant injuries and/or damage, and factors that serve to aggravate losses following the event. As recently as November 1968, Hofmeister and Pfister noted: "The agricultural industry has lagged behind others in determining the nature and extent of injuries to farm people. There have been very few extensive studies of the total accident problem in agriculture." (52:1).

The need to establish a farm accident reporting system is further underscored by the fact that on a national basis, although accidents involving farm tractors were a significant contributor to work-related fatalities (up to 40 percent), they represented as low as 2 percent of those work-related accidents resulting in injury. (Estimate derived from National Safety Council data.) (107). Thus, it is clear that proper safety management requires that all accidents related to the farm operation, not just those related to tractors alone, are recorded in order that they may be effectively treated on a systematic basis. As a minimum, it is recommended that a farm machinery (including tractors) accident reporting system be established.

Officials of the farm equipment industry and agricultural safety research agencies appear to be unanimous in their support for the establishment of a reliable farm machinery accident reporting system (see Proceedings of the Public Meeting, Appendix B). Further, nearly two of three farmers polled in a recent survey conducted by TOP Operator, a Farm Journal publication, indicate a need for more useful information concerning agricultural tractor accidents (Appendix B: B13). It is worthy of note that those farmers who feel that present information is adequate reside in States where active farm safety programs have been established.

Little understanding of the cause and effect of farm accidents and injuries can be gained from statistics gathered principally from newspaper clipping services or files accumulated for other purposes (i, e., insurance claims, vital statistics, highway accident files oriented primarily toward the collection of information concerning automobile, bus and truck accidents). Efforts have been made in the past to develop and implement a farm accident reporting system rivaling the goals of highway or other industrial safety programs. These efforts have been hindered by a lack of proper support. Coordinated and continuing support must be provided if future efforts are to be productive.

Succeeding sections of this report will review previous methods utilized to collect farm and highway accident data. An assessment will be provided of their utility with respect to meeting the information requirements and immediate program needs of a farm machinery accident reporting system. Following this discussion, guidelines will be outlined for establishing a recommended system for reporting farm machinery accidents. The guidelines would require nominal change if it is deemed advisable to reduce the scope of effort to include tractor accidents only or to increase the scope of effort to include all work-related accidents in general.

6.1 Assessment of Current Methods of Farm Accident Reporting

In its report, Product Accident Reporting Feasibility Study, the National Safety Council (NSC) stated:

> "The specific requirements of the product accident data-gathering program must be defined before a data-gathering system can be established. After the program objectives have been determined, the criteria can be applied to the sources and matched with relevant parameters--such as the funds available, manpower, time available. The assigned priorities of the system determine the methods and sources that can be used. In short, there is a need for long-range planning and coordination if a product accident data-gathering system is to be feasible; this planning must recognize the limitations of the system goals in order for the system to become an effective force in the safety field." (103:7).

The NSC report may be examined for an assessment of the capabilities of a number of accident reporting methods beyond those used for farm and highway accident reporting and including those known and in practice at the time that report was prepared. The philosophy as extended by the above guidelines was used by NHSB to provide an assessment of previous methods of collecting useful farm and highway accident data.

The program objectives of a farm tractor accident reporting system have been established by Congress. In calling for ". . . a report on the extent, causes and means of prevention of agricultural tractor accidents on both public roads and farms. . . ." Congress has requested that information be provided concerning the magnitude of the tractor accident problem, the causes of farm tractor accidents, identification of hazards most likely to produce injury, and recommendations on means of preventing the occurrence and reducing the severity of these accidents. It is also assumed that information should be sought to determine the effect of these recommendations, once enacted.

Information requirements necessary to meet program objectives are extensive. The large number of topics addressed in this report serve to indicate the scope of effort required in the collection of data concerning accident or injury causes and those factors that serve to aggravate losses following the event. Figure 43 provides an overview of the data necessary for the study of highway-related accidents, including farm machinery accidents.

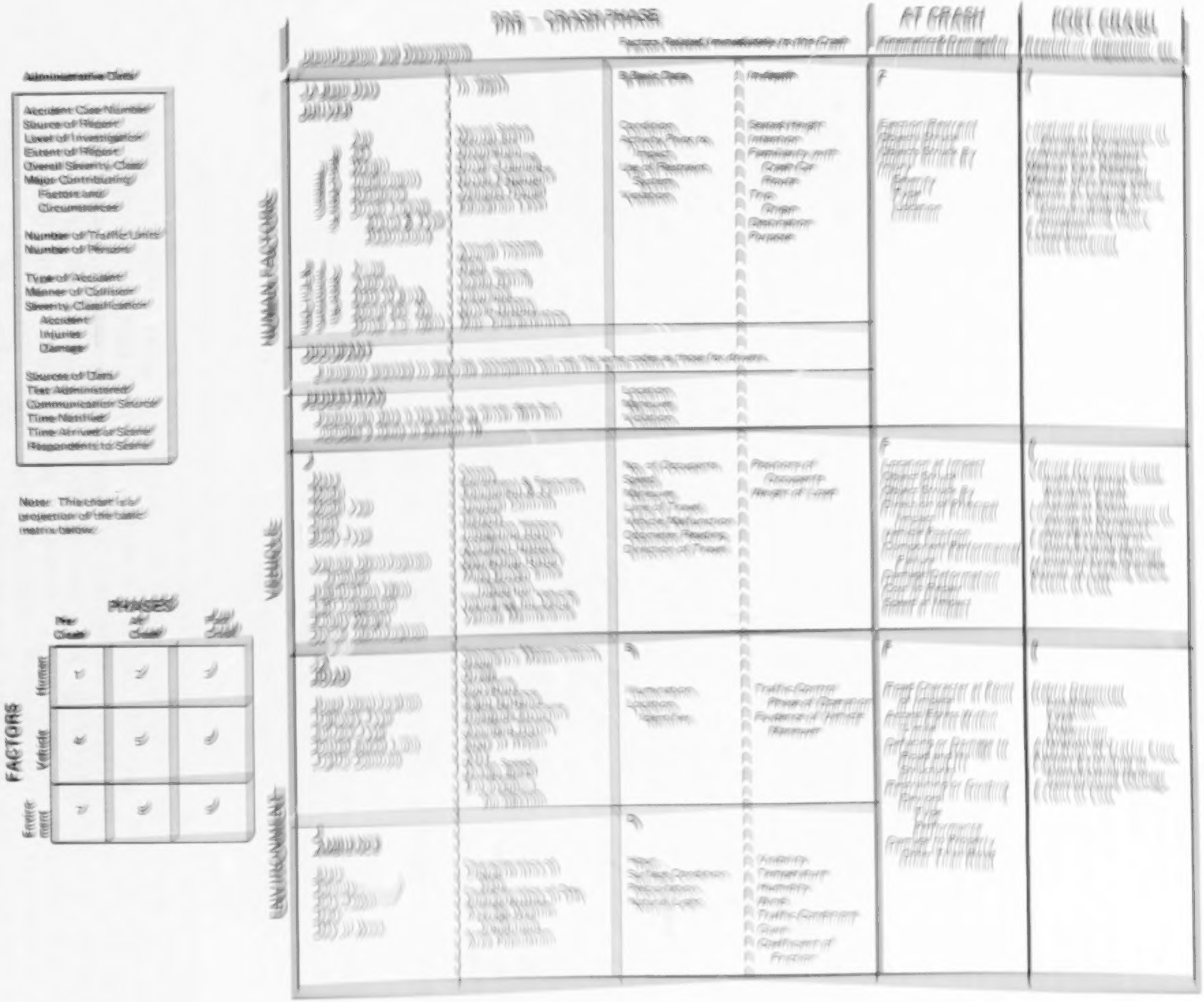
The capability of a particular data collection method to meet the program objectives and obtain the required information may be assessed by noting the influence of time, manpower and funding limitations, and abilities of the reporting personnel. An assessment of the capability of existing farm and highway accident reporting systems to satisfy the above requirements is provided below. This assessment will be discussed in three groupings, (1), accident survey reporting, (2), owner-operator reporting, and (3), on-scene reporting, reflecting the timeliness with which information regarding the accident is obtained.

6. 1. 1 Accident Survey Reporting Capability

Accident survey reports are those that are based on information collected through personal interviews or the use of questionnaires and conducted relatively long after the fact.

A. Bi-Level Accident Surveys

One of the more recent methods utilizing accident survey reports has been the system employed by cooperative extension services of State land-grant universities, operating under "starter" grants provided by the National Safety Council. (104). Volunteer workers are solicited from the farm community by county agricultural agents and trained by members of the program staff. A randomly selected sample of farm families is personally contacted on a periodic basis (four times in a one-year period) by these trained volunteers. Information is collected regarding accidents that resulted in injury of a defined severity


Administrative Data
Accident Case Number
Source of Report
Level of Investigation
Extent of Report
Overall Severity Class
Major Contributing Factors and Circumstances
Number of Traffic Units
Number of Persons
Type of Accident
Manner of Collision
Severity Classification
Accident
Injuries
Damage
Sources of Data
Test Administered
Communication Source
Time Notified
Time Arrived at Scene
Respondents to Scene
PHASES
Pre-Crash
At-Crash
Post-Crash
FACTORS
Human
Vehicle
Environment
1
2
3
4
5
6
7
8
9
PRE - CRASH PHASE
Factors Related Immediately to the Crash
AT CRASH
POST CRASH
HUMAN FACTORS
VEHICLE
ENVIRONMENT
B) Basic Data
In-depth
Condition
Activity Prior to Impact
Use of Restraint System
Violation
Seated Height
Intention
Familiarity with Crash Car
Route
Trip
Origin
Destination
Purpose
Ejection/Restraint
Object Struck
Object Struck By
Injury
Severity
Type
Location
Location
Maneuver
Violation
No. of Occupants
Speed
Maneuver
Line of Travel
Vehicle Malfunction
Odometer Reading
Direction of Travel
Positions of Occupants
Weight of Load
Location at Impact
Object Struck
Object Struck By
Speed at Impact
Illumination
Location
Hazards
Traffic Control
Phase of Operation
Evidence of Vehicle Maneuver
Weather
Surface Condition
Precipitation
Natural Light
Visibility
Temperature
Humidity
Wind
Traffic Conditions
Glare
Coefficient of Friction

Note: This chart is a projection of the basic matrix below.

FIGURE 43

to persons living, working, or visiting on the farm. A data collection technique termed as being "bi-level" in nature has been used to collect this information:

- A "regular survey questionnaire" is employed to collect general data to indicate the approximate number of farm-related accidents resulting in injury, broadly defined activities in which the victims were engaged, some indication of how the accident happened, the extent of losses, etc.

- A "Supplemental Accident Form" is used to obtain more detailed information on specific accidents than would result from the regular survey questionnaire. This form is completed by the trained volunteer when these accidents are noted in the course of conducting the survey interviews.

This type of program has been successfully utilized in three States to date under grants by the NSC. NSC plans call for the ultimate development of a program involving all fifty States. The country would be divided into ten regions of five States, with each State per region conducting a year-long accident survey once every five years.

A third-level of reporting is acknowledged and if it is employed, the "bi-level" system is referred to as being "tri-level" in nature. Still further information is pursued regarding particular accidents of interest. Research teams of scientists are employed to seek in-depth and technical information, beyond the capabilities of a volunteer with limited training. To date, this third-level has not been employed.

B. Surveys of Particular Accidents

Another type of accident survey involves the collection of information concerning accidents of a particular injury severity or type through the use of mailed questionnaires or contact by persons on the research team. Various means are utilized to identify accidents fitting study criteria. Newspaper clipping services have been a popular device, since it is anticipated that accidents of a catastrophic nature (those involving death or high injury severity), accident types of community interest, or those of an unusual nature will be reported in local newspapers or trade journals. Other techniques have been used to identify accidents meeting study criteria. These include screening vital statistics, insurance or workman's compensation files, appealing to the public for information through news articles, and responding to items mentioned in casual conversation.

C. Assessment of Accident Survey Reporting

Accident survey reports are collected some time after the fact and depend upon the recall capabilities of the party interviewed or upon the availability of durable evidence. They cannot satisfy all information required for a full study of the problem. Increasing the frequency with which survey reports are made may increase the quality of information collected since this lessens the need for long-term recall. However, this presumes that the person interviewed was skilled in the examination of a large number of factors, was in a position to examine the evidence, and had the foresight to retain information concerning the evidence. The person interviewed is usually the one involved in the accident or someone who has knowledge of the event by virtue of association. The abilities of these persons to provide adequate data are limited. (66).

The accident survey, if used in its proper context, can provide a great deal of useful information economically. Bi-level accident surveys are designed ". . . to generate statistics on a representative sample that will give the overall accident experience. This includes accident exposure data, frequency and severity rates, and trends of accidents if carried out over a long enough period. . . ." Through the use of varying formats, these surveys ". . . can give detailed information on selected accident types or on any aspect of accident experience of interest [within the capabilities of those reporting the data and as limited by the time delay between time of accident and time of survey] to the investigators." ([illegible]).

6.1.2 Owner-Operator Reporting Capability

Owner-operator reports include those forms filed by the farm owner, adult member of his family, or hired hand when an accident occurs meeting certain criteria. If farm members are involved in an accident of a certain severity which occurred on the public highway, many States require that a written report concerning certain details of the accident be submitted to a designated authority. Similarly, certain details of the circumstances resulting in all accidental deaths must be reported. Workman's compensation bureaus and insurance companies require details of the event to be reported when a claim is submitted. These reports are usually prepared shortly after the incident and in more comfortable surroundings than the accident scene.

Owner-operator reports have limited application to research. They are usually designed for administrative or operational needs of the agency requiring the report. The person submitting the report may depend on recall or witness statements to complete the form. The information at hand is dependent upon his exposure to the event, time elapsed before completing the report, and his ability as an observer. The information may be presented in such a manner as to absolve the person of responsibility for the accident and/or lend further credence to the validity of his claim.

Due to these limitations, only general information concerning the accident is consistently available for research efforts.

6.1.3 On-Scene Reporting Capability

On-scene reports include those accident reports where certain information is collected at the accident scene by civil authority or researcher, upon notification of the event.

A. Police Highway Accident Reports

If the accident occurs on the public highway, civil authorities -- usually the local police -- complete and file reports at local and State levels. These highway accident report forms are designed to satisfy the administrative and operational needs of enforcement and regulatory agencies. The forms are planned primarily for the consistent collection of general information concerning automobile, bus and truck accidents. Relatively little direction or training is given for the collection of information concerning accidents of a unique nature such as those involving farm machinery.

B. Police Incident Reports

A second type of on-scene reporting involves the completion of an incident report by the police when called to the scene of accidents that occur on private property. Specific forms usually are not used. The only record which may be retained officially is a brief description of the accident, its location, response time, and actions taken by the attending officer.

C. Special Investigators Reports

Another type of on-scene reporting involves the use of investigators, specifically trained in the collection of research data. These investigators attend the accident scene following notification that the accident is of interest to the study, and usually with the permission of local authorities or individuals involved. Depending upon their degree of training and background, the availability of information, and requirements of the research effort, varying levels of information are obtained. Reports concerning an occurrence may range from a structured, single page form, to a detailed epidemiological report concerning the status and interaction of all potential contributing factors to the accident event.

D. Multilevel Highway Accident Reporting Systems

Each of the above methods has some degree of utility in the collection of useful research data. Two recent concepts designed to combine the best aspects of each of these systems have been developed and implemented in the field of highway safety.

(1) Bi-Level On-Scene Reporting

A bi-level accident reporting system, using on-scene reporting capability, has been developed by the National Safety Council. (103). Programs have been conducted on a State level utilizing police personnel to generate two levels of data. The cooperation of local police agencies is elicited and personnel are trained by members of the research staff. A data collection technique, forerunner to that described for the bi-level survey, has been utilized to collect information at the accident scene.

Supplementary report forms are used to obtain more detailed information on certain types of accidents or particular aspects related to the event. These forms are completed by the police at the time they attend the scene of an accident meeting study criteria.

This system of reporting is employed when cost considerations preclude the use of an independent work force to generate such data. The police provide a 24-hour, 7-day week data collection capability with personnel already exposed to varying degrees of investigative training. However, other functions related to accident scene attendance take first priority -- directing the protection and clearing of the accident scene, care and removal of the injured, and determining violations of the law. These duties, combined with the fact that varying levels of training are represented, prevent the collection of highly detailed or extensive data per study effort. Formats are designed to address problems within the capabilities of the investigator and the bi-level system is designed to be repeated until all areas related to the problem are investigated.

(2) Tri-Level On-Scene Reporting

The National Highway Safety Bureau (NHSB) is currently sponsoring two Tri-Level Highway Accident Investigation Studies (Figure 44). Three levels of effort are combined in these studies in order to statistically validate the findings of in-depth, on-scene traffic accident investigations.

Level I of each study provides accident rate, exposure, and frequency information collected on the entire driving population in the area under study. State and private agency records are utilized to provide this information.

INTEGRATED
TRI-LEVEL
ACCIDENT
INVESTIGATION
STUDIES

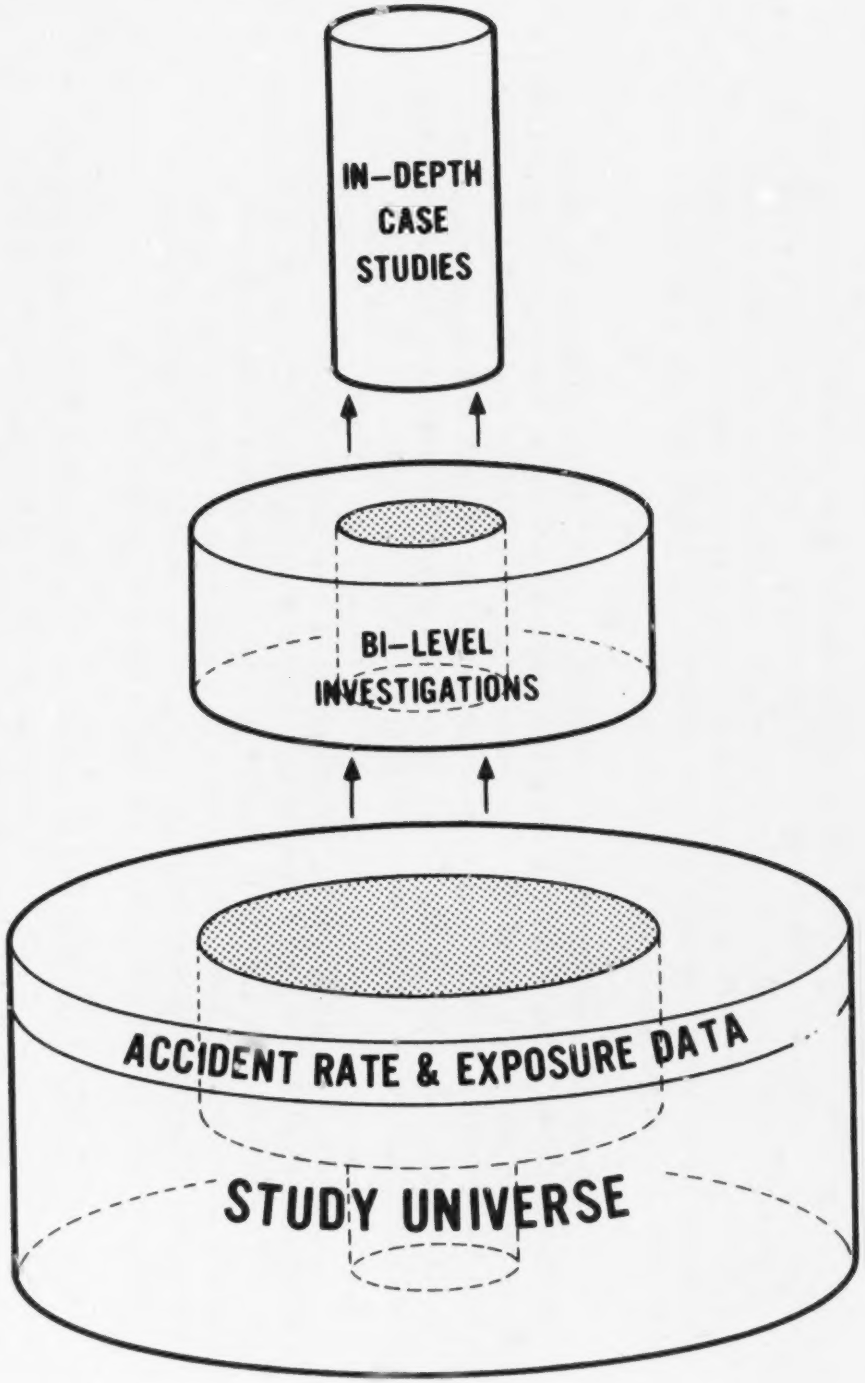

IN-DEPTH
CASE
STUDIES
BI-LEVEL
INVESTIGATIONS
ACCIDENT RATE & EXPOSURE DATA
STUDY UNIVERSE

FIGURE 44

Level II combines data collected by the police with selected causal and/or injury information collected by scientific investigators for a designated subset of all accidents reported in the study area. The subset may be all accidents involving certain features of vehicles produced over the last two model years. In each project, at least 3,000-4,000 accidents fit the criteria.

Level III constitutes a subset of Level II accidents in which multidisciplinary on-scene investigations are conducted (approximately 200 in each project) to yield a substantial number of in-depth, clinical cases to provide statistical significance to accident and injury causation findings. Level III findings are also used to validate the accuracy of data collected at the lower levels.

With this approach, significance can be attached to in-depth findings (Level III) when compared with the exposure (Level I) information. Trends in the Level II findings can be validated by the more reliable in-depth (Level III) findings. Statistical analyses can be performed on clinical investigations which will yield the most reliable causal and injury information in highway accidents to date.

Although this tri-level study is a comparatively new concept which is still in the formative stage, preliminary findings resulting from these studies have already provided the NHSB with valuable highway safety information. Two more tri-level efforts are being planned by the NHSB in the near future.

The use of an on-scene reporting capability permits an opportunity to collect and analyze all available evidence related to the accident. Investigators are exposed to the accident shortly after its occurrence and may examine all evidence related to the event on a first-hand basis. Systems may be designed to ensure that the data collected is statistically significant, and that investigators with appropriate background and training are utilized per the areas under study. All levels of information detail may be satisfied, limited only by funding and available manpower. In the latter respect, the application of on-scene reporting systems to meet all information requirements is not recommended. More economical systems, e. g., accident surveys, are recommended where it is feasible to satisfy information requirements related to the study of certain aspects of the farm accident problem.

6.1.4 Summary of the Problem

The need for a farm machinery accident reporting system is recognized. It should encompass not only the study of tractor accidents but, as a minimum, all farm machinery accidents. Agriculture is national in character but regional as to type of farming. A final manager of any farm safety program is the farmer himself. Therefore, the reporting system must be able to provide information regarding the farm machinery accident problem on a national, regional, and local basis, to insure the effective use of available resources at all levels.

It has been determined that none of the existing methods of collecting machinery accident data as documented in this report could independently provide all necessary information to satisfy the program objectives. A need exists to pursue a program that would combine the best aspects of each method of accident reporting. Such a program would permit:

- Transient data, and that information which requires special skills to ensure accurate reporting, to be acquired through an effective on-scene reporting capability.
- Durable data, and that not dependent on special reporting skills, to be more economically obtained through use of an effective survey capability and/or use of existing information files.

To provide a systematic, nationwide attack on the problem and a practical answer to information needs, the program should be devised to ensure that all methods utilized to collect useful farm machinery accident data are coordinated by a single Federal agency, and act within established channels of authority.

This agency should be authorized as the repository for all farm machinery accident data on the public road and the farm. This would aid in efforts to harness local, public and private resources in collecting such information and lend official public recognition of the benefits to be derived.

Guidelines have been devised to establish a National Farm Machinery Accident Reporting System that would permit the collection and analysis of sufficient data to measure the farm machinery accident problem. These guidelines reflect current approaches to the collection of useful accident information while considering the practical problems of obtaining such information within the farm population and while utilizing existing facilities and resources to their maximum to formulate an economically practical system.

Due to time limitations, certain aspects of the problem have been treated generally. It is anticipated that development and implementation of a working system will reveal problems not fully considered here.

Succeeding sections will treat organizational needs, program objectives, a proposed methodology, reporting criteria, notification needs, measures to increase public cooperation, report forms and records, and immediate program priorities necessary to implement the National Farm Machinery Accident Reporting System.

In an independent effort, the National Safety Council (NSC) prepared and submitted a paper concerning "agricultural tractor accidents and reporting procedures" and two NSC study reports entitled, Product Accident Reporting Feasibility Study, and A Suggested Procedure For Collecting Farm Accident Data. Due to space limitations, these reports are not included in the Appendixes of this report. It should be noted that a great deal of information and background experience related to accident reporting systems is contained in them. The paper, however, is included in the Appendix and draws heavily upon this background and experience. (Appendix A:A185).

To the casual reader, it may appear that there are significant differences in the reporting systems recommended by NSC and the NHSB. The major difference is whether it is necessary and economically feasible to support an on-scene reporting capability for farm machinery accidents. This capability is believed necessary by NHSB, and it is believed economically feasible if efforts are made to develop this capability through existing Federal and State organizations. Similarly, it is believed that farm equipment and slow moving vehicle accidents on the highway should be addressed by a single effort, feeding information to both the farm and highway safety communities.

Finally, in the section which follows, it is recommended that an organization be authorized to develop and coordinate a National Farm Machinery Accident Reporting System. The NSC and NHSB systems are offered for consideration. It is recommended that the accident reporting system utilized be selected by this organization and reflect a consensus of the farm safety community.

6.2 A National Farm Machinery Accident Reporting System: Recommended Program Guidelines

6.2.1 Organization

A centralized and coordinated national effort is required to develop an effective farm machinery accident reporting system. Present efforts are scattered and lack a systematic approach to the problem. The first and primary responsibility of those parties now concerned with the establishment of an effective reporting system should be to identify, empower, and provide continuing support to a single agency or organization that would develop and coordinate a National Farm Accident Reporting System. It is imperative that the agency be one that is identified by all members of the agricultural safety community as serving their interests. The agency should be guided in its program development by an advisory committee consisting of representatives of the farm community, agri-business interests, independent research agencies and Federal, State and local governments. The cooperation of these groups is vital to the proper development and implementation of a system which is national, regional and local in scope.

6.2.2 Program Objectives

The National Farm Machinery Accident Reporting System should, as a minimum, ensure that:

- All safety hazards related to the farm environment as they affect farm machinery operation are recognized.
- The relative magnitude of various hazards are determined in order to provide a proper base for the development and implementation of remedial measures.
- Reliable data as to the cause and effect of these hazards is obtained for the information of those responsible for developing countermeasures programs.
- The effectiveness of countermeasures are assessed. More efficient or effective remedies should be introduced as priorities change or as new safety hazards are recognized.
- An annual report is made that summarizes the accident and fatality experience over the year and provides a statistical base for evaluating the effect of various countermeasures on this experience.

6.2.3 A Proposed Methodology for Studying the Farm Machinery Accident Problem

The methodology employed for studying the farm machinery accident problem should develop statistically reliable data to portray the farm tractor accident problem on a national, State and local basis. It should have the flexibility to ensure the collection of all available pertinent data. Survey methods and information files should be used to collect long-term durable information. However, on-scene collection of information by trained investigators is necessary to ensure the collection of transient or perishable data, and the collection of data which is beyond the capabilities of persons with little or no training. A suggested concept is a system to combine the better aspects of survey methods, use of information files and on-scene reporting capability. This system would consist of three levels of effort:

- A basic level to collect general exposure data indicating the approximate number of farm-related machinery accidents occurring within a region, broadly defined activities in which the victims were engaged, some indication of how the accident happened, extent of losses incurred, etc. Survey methods and/or the use of existing agency information files would be appropriate for this purpose.

- A second level which concentrates on collecting detailed information on a particular accident type, such as accidents involving specific models of tractors. Supplemental report forms, oriented toward the collection of data by persons with varying degrees of training, would be completed at the time basic level information is obtained on a survey basis, when specially trained investigators are deployed to the scene upon notification shortly after the event, or when police officers attending the scene are utilized in a cooperative effort.

- A third or in-depth level, utilizing multidisciplinary teams of scientists, employed to seek in-depth information beyond the ability of personnel with limited training. This information would be used in furthering knowledge of factors contributing to the causes of farm machinery accidents and injuries, suggesting hypotheses, developing equipment and techniques, and the establishment of sampling tests to verify hypotheses. Implementation of the third level would be limited to selected areas due to cost considerations and logistical difficulties.

It is recommended that the scope of the farm machinery accident problem be considered as a machinery-associated accident occurring to any person living, working or visiting on the farm. This would include accidents occurring both on and off the farm.

Two independent but related programs would be established by the coordinating agency to collect and analyze data concerning on and off the farm accidents. These programs would be performed in the same area and during similar time periods in order to provide data valuable to both farm and highway safety efforts. The combined programs would be conducted as described below.

A. Farm Machinery Accidents on the Highway

One program would address the problem of accidents involving slow moving vehicles on the highway -- that is, those accidents involving automobiles, trucks, farm equipment, etc., which by virtue of limited operating speed and maneuverability exhibit a speed differential conducive to accidents.

This program would be conducted at a State level and would logically be directed by the NHSB as the designated highway safety agency. It would employ a Statewide, bi-level on-scene reporting system (see Section 6. 1. 3 D(1)), utilizing police personnel to collect both levels of on-scene data. It would be preferable that this study be performed in a State where NHSB currently has established a multidisciplinary highway accident investigation team. These teams could be dispatched to selected accidents to obtain detailed information on the SMV problem.

Directors of this program would be responsible for sufficient data analysis to relate the slow moving vehicle accident problem to highway safety efforts. Raw data reports concerning farm machinery accidents on the highway would be forwarded to those responsible for addressing the problem of farm machinery accidents (see below).

B. Farm Machinery Accidents on the Farm

The second program would address the problem of all farm machinery accidents; that is, all machinery accidents occurring to any person living, working or visiting on the farm. This program would be directed by an agency with the capability to establish Statewide, tri-level reporting systems through an existing organization.

A third-level on-scene reporting capability would be established and, as with the slow moving vehicle program, multidisciplinary teams would be dispatched to selected accidents to study scientifically all aspects of the farm machinery accident problem. Personnel would also be responsible for program direction and analysis of all data. Collaboration with NHSB accident investigating teams would broaden geographical coverage in attacking common problems. (See third-level discussion -- Section A.)

A second level on-scene reporting capability would also be established. Second-level investigators would be so deployed as to ensure the widest possible area of coverage per man conducive to on-scene response. Their primary function would be on-scene reporting of on-farm machinery accidents. A secondary function would be to support bi-level highway safety efforts where investigative services of local police are not available. As noted in the preceding section, raw data concerning off-farm, highway-related farm machinery accidents would be fed into the system and follow-up studies could be initiated to complement the highway accident reports.

A basic level effort would be established to provide exposure data to reveal the magnitude of the overall farm machinery accident problem. The bi-level survey technique (see Section 6. 1. 1 A) would be a useful system for this purpose. The survey would permit an evaluation of the effectiveness of the on-scene reporting system, generate cooperation among the farm community to report accidents, and answer exposure and durable data needs.

6.2.4 Reporting Criteria

There is an immediate requirement for basic data with which to attack the problem of farm machinery accidents. There is such a wide variety of accident types due to the wide range of activities connected with farm operation, that it is suggested that data collection efforts not be limited to accidents of a particular severity. It is suggested that data be collected for farm machinery accidents of all severity levels including death, personal injury or property damage, and for near-miss situations. This would permit data to be collected on a large number of incidents within a given population or study area. The reporting of accidents resulting in property damage only and near-miss situations would permit information to be collected concerning pre-accident causal influences without fear of legal liability. The reporting of near-miss situations would yield information about successful accident avoidance techniques and the effectiveness of remedial measures.

Near-miss situations would include those incidents which did not result in personal injury or property damage because:

- Imminent danger was understood and successful avoidance techniques were initiated. For example, a tractor operator might be working along the edge of an embankment. For some reason -- loss of operator control, vehicle malfunction, loose ground, or other factor, (data to be collected) -- the tractor would pass over the edge. Through a series of operator maneuvers (information to be taken on maneuvers) an accident would be avoided.

- A hazard was avoided. The situation or the hazard was recognized after reaching "a point of no return" or after returning to a point of safe operation. Using the same example, the operator might "freeze" and take no apparent action, but for some reason, redirection by the ground surface, vehicle self-recovered, etc., an accident was avoided (the reason to be determined).

- A hazard was not avoided, but no personal injury or property damage resulted. Using the same example, the accident might not be avoided, and the tractor might overturn. Property damage might be nominal and the operator might emerge unscathed. Why this was so would be the subject of the investigation.

It is also recommended that the extent of detail, especially for basic and second-level efforts, be governed by the infrequency of particular accident types. (104). The degree of detail required should be limited only by the expertise of those collecting the information and limitations of time and expense.

6.2.5 Notification of Accidents

It is feasible to use on-scene reporting techniques in the collection of farm machinery accident data. (67, 68). It has been reported that it has been difficult for an independent research agency to be notified of accidents shortly after they occur. Similar observations have been made with respect to the investigation of highway accidents.

Previous efforts have elicited the cooperation of police, hospitals, wreckers, ambulance services, etc., to inform researchers of an accident. Police agencies are notified by those involved in highway accidents because it is usually required by law if injury or property damage above a certain level is incurred. In the event of an accident, especially those resulting in injury, one phone call placed through the police ensures the dispatch of all emergency services. The extent of property damage or injury determines the emergency services required. The degree of cooperation extended by these agencies to relay word of the accident to researchers appears to be related to:

- The researcher's reputation for conducting useful research efforts in the past.
- Recognition by the agencies of the public welfare benefits which might accrue.
- The length of the program -- certain agencies will accept short-term notification responsibilities.
- Overload of agency communication facilities, especially shortly after word is received or during peak periods for all communications.

The research agency selected should have demonstrated research ability and be well-known for their public efforts. It should be feasible to establish a system whereby notice of accident occurrence is relayed to the research agency through emergency services communication facilities. This requires that appropriate measures be taken to ensure a high level of cooperation. The following suggestions are made in this respect:

- Program efforts should be short-term to encourage maximum cooperation of various agencies. One year efforts appear to be acceptable and studies should be designed to acquire needed data within this period.
- Notification and on-scene reporting within 24 hours after the accident should satisfy research requirements. This would alleviate communication overload and permit each team to cover a wide geographic area. It would also provide an opportunity for those involved to report the

occurrence directly to the researcher. More immediate notification would be desirable to ensure against loss of evidence.

6.2.6 Cooperation of the Farm Community

Recent efforts to collect farm accident data through the use of survey techniques by trained volunteers have been successful. Farmers who have been asked for data have been most cooperative. (104).

The cooperation of those directly involved in the accident must be obtained in order that the investigator is exposed to all pertinent evidence. On-scene investigations, by their nature, must proceed under the specter of legal liability. The person involved in an accident must evaluate on the spot the legal implications of permitting the on-scene investigation to proceed, especially for those accidents which involve his property and his direct participation. Although the data collected is for research purposes, the data and/or the investigator may be subpoenaed in later legal action. On the other hand, the survey report, by its timeliness, may assist in the resulution of legal questions.

In the public interest, the researcher must take every precaution to minimize legal implications. Reports should be devoid of all information that would permit case identity and only mass statistics can be maintained. This necessitates careful planning of processing and analytical techniques. New techniques cannot be incorporated based on knowledge gained during the data collection process. Nor can open case files be maintained until all information is at hand. Nor can a case be reopened in order to examine late developments. To secure maximum cooperation, the parties involved should be advised at the outset of the measures taken for their protection.

At present, the researcher must rely upon his reputation for conducting useful research and acting in the public interest in order to gain cooperation. The agency chosen to manage this program should have this quality also. Other actions have been taken to minimize legal implications. In the case of highway accidents, the Congress has been presented with an appeal by NHSB that research information, collected by NHSB for the public welfare, be declared privileged research information, and not be available for any other purpose. Similar consideration might well be extended to any agency acting on behalf of the Federal or State government in connection with the investigation of farm machinery accidents.

6.2.7 Report Forms and Records

Accident report forms and record systems are the foundation of any accident reporting system. A number of forms have been suggested for reporting machinery accidents by various researchers in public and private agencies. Developing a composite of these forms probably would reveal the scope of the problem, but might be bulky and cumbersome. The data collection methodology proposes a flexible reporting format, though certain information requirements should remain fixed for comparative purposes. The flexible format provides supplemental report forms for use when detailed information about a particular problem is needed. The introduction of varying levels of skilled investigators to address particular problem areas is suggested.

6.2.8 Immediate Program Priorities

- As noted previously, the first responsibility of those concerned with the establishment of an effective farm tractor accident reporting system should be to identify and provide continuing support to an agency or service that will develop and implement the system.

- The attention of the farmer and farm safety community must be focused on the need for more useful farm tractor accident information and the benefits that could ensue. All should realize that uncoordinated efforts result in little reliable knowledge of the problem. The cooperation of the farmer is vital to the notification of accidents and the collection of useful data, especially for those accidents occurring on farm property. A maximum effort must be made to ensure his cooperation. Also, although agriculture is one of the basic industries in the United States, it is comprised of many thousands of private enterprises. If safety were left to the individual, he would be dependent on his own experience. In a coordinated effort, he may gain from the experience of many in supporting basic research as to the cause and deterrence of accident and injury and be afforded expert assistance for safe and efficient farm management programs.

- It is suggested that pilot programs be established on a Statewide basis to investigate the feasibility of providing an effective data reporting mechanism. These programs would serve as a model for the development of a fully operational National Farm Machinery Accident Reporting System.

- It is believed that a fully operational system would involve all fifty States. The country would be divided into five regions of ten States, with each State per region conducting a year long accident survey once every ten years.

CHAPTER SEVEN

7.0 Findings, Conclusions and Recommendations

A study has been undertaken on the extent, causes and means of prevention of agricultural tractor accidents on both public roads and farms. This report of the results of that study has been structured in such manner as to provide an estimate of the number of deaths and injuries resulting annually from agricultural tractor accidents, and identification of the primary causes of such accidents, including consideration of the hazards most likely to cause death or injury. Also consideration has been given to the present situation in reporting accidents and injuries, with guidelines presented for a uniform reporting system.

What remains is a summary of study findings and conclusions contained in preceding chapters, and recommendations on means of preventing the occurrence of, and reducing the severity, of injuries resulting from agricultural tractor accidents.

7.1 Findings and Conclusions

The principal findings of the study are as follows:

7.1.1 Magnitude of the Problem

- Available data indicate that the annual number of farm tractor fatalities on both the farm and public road is between 800 and 1,000. All indications are that this number has remained relatively constant, or perhaps has even decreased slightly over the past five years. (2.1).
- Data do not exist from which to estimate the annual number of non-fatal tractor accidents. One study in North Carolina suggests a ratio of a little over eight recorded injuries to one death from tractor accidents on the highway. (2.5).
- From two-thirds to three-quarters of the tractor fatalities occur on the farm with the remainder on public roads. (2.6).

- Approximately 60 percent of the fatal accidents result from tractor overturns, with side overturns predominating over rear overturns by a factor of about three to one. The number of front overturns is negligible. (2. 7; 2. 8).

- Age of the tractor population is critical to any imposition of tractor safety standards since new tractors sold each year represent only about 3. 3 percent of the total population. The everage tractor age is 14. 3 years. (2. 4. 1).

7. 1. 2 The Role of the Tractor

- There is no single factor involved in tractor overturns; understanding is required of tractor stability characteristics and design features, and of tractor relationships with operating and environmental conditions. (3. 1).

- The principal countermeasurefor ameliorating the effect of overturn accidents is the overturn protective frame in the form of rollbar or cab, designed to meet standards developed by the American Society of Agricultural Engineers (ASAE) and the Society of Automotive Engineers (SAE). (3. 1. 4).

- All tractor manufacturers now market roll-protective equipment; however, non-protective cabs also are marketed by three of six tractor manufacturers surveyed and by "will-fit" companies which do not provide overturn protection. (3. 1. 4).

- Customer non-acceptance and unwillingness to pay have been significant factors affecting the introduction of roll-protective devices; at present, however, about 20 percent of all new tractors are said to be equipped with roll frames or cabs meeting ASAE standards. (3. 1. 4).

- Overturn protective frames are available for retrofit of most tractor models produced after 1963. Retrofit of tractors manufactured prior to that time in most instances, however, requires major and costly alterations, including redesign of the tractor rear axle housing. (3. 1. 4).

- Almost every PTO accident involves the entangling of the victim's clothing by the rapidly revolving shaft and produces serious injuries, some of them fatal. Substantive design changes being made are expected to reduce the possibility and seriousness of such accidents. (3.2).

- Operation of tractors and associated implements constitutes a health hazard; e.g., noise, exhaust fumes, dust, pollens, toxic chemicals, heat, cold, sun's rays, vibration, flying material from breakage of equipment. The introduction of the cab which provides acoustic, vibratory and atmospheric controls should help minimize some of the medical problems resulting from excessive exposure to such hazards. (3.3).

- Technological advances and productivity factors in recent years have served to provide improved tractor safety; e.g., hydraulic self-equalizing brakes, uncluttered operator platform, mounting and dismounting aids, three-point hitch, independent PTO drive, improved fuel tank and its location. However, not all tractors, particularly the smaller ones,are so equipped. (3.4.1).

- Redesign changes suffer from lack of benefits obtainable from careful task analysis of tractor and associated machinery operations. (3.4.1).

- A comparison of currently-produced tractors with 1940 models provides an impressive list of about two dozen added safety features. (3.4.3).

7.1.3 The Role of the Operator

- Causal relationships between biographical factors (age, sex, eductional level, operating experience), knowledge and skill requirements, and medical factors concerning tractor operators and tractor accidents cannot be satisfactorily demonstrated at this time due to lack of hard data. (4.1; 4.2; 4.3).

- Many different organizations currently contribute to instructional programs for safe tractor operations -- e.g., U. S. Department of Agriculture, Department of Labor, Department of Health, Education, and Welfare, vocational schools, State agricultural colleges, FFA and 4-H Club, National Safety Council, Farm and Industrial Equipment Institute, and the tractor industry itself. (4.4)

- Training programs for 14- and 15-year old tractor operator candidates have been stimulated by the Hazardous Occupations in Agriculture Order issued by the Secretary of Labor and in effect since January 1968. (4.0)

- Inadequacies noted in several of the tractor operator training programs include:

  -- Failure to point up certain characteristics of the machine critical to safe operation.

  -- Failure to point up selected emergency-type situations and the performance necessary to avoid accidents or minimize its consequences.

  -- Lack of attention to the post-crash (loss limiting) phase of tractor accidents.

  -- Insufficient attention to hazards of tractor operation, and means for eliminating or minimizing such hazards.

  -- Lack of formal plans for evaluating training programs beyond testing during program. (4.4.4).

- The driver of a farm tractor need not have a driver's license for operating the machine off the public highway. For operation of the farm tractor on a public road, the Uniform Vehicle Code would require a driver's license but the laws of most States do not. A Federal Certificate of Training, however, is required for 14- and 15-year old farm employees under the Hazardous Occupations in Agriculture Order. (4.5).

- Insufficient information exists concerning non-operator victims of tractor accidents. Passengers on tractors are among such victims although the tractor industry and formal training programs discourage non-operators riding on tractors. (4.6).

7.1.4 The Role of the Environment

- Because of its multifunctional role in farm operations, the tractor is assumed to have capability of operating over almost any terrain in any kind of weather, and of performing any power-related task permitted by the elements. Under these conditions, accident situations are propagated. (5.0).

- Few tractor accident studies and reports provide more than superficial attention to the role of the environment in the machine-man-environment interface of accidents, injuries and deaths. (5.1).

- Only limited countermeasures directly related to the farm environment have been developed. The environment is considered relatively non-changeable so far as tractor operations are concerned. Hence, countermeasures are applied primarily in tractor design and tractor use. (5.2).

- At least one-fourth of all tractor accident fatalities are believed to take place on public roads. (5.3).

- Although the problem of tractor and associated farm machinery safety is primarily one related to farm operations, use of public roads by tractors as slow moving vehicles (SMV) amidst motor vehicles designed for high speed is of concern:

  -- Collisions between farm tractors and other motor vehicles appear to be the most common type of tractor accidents on the public road.

  -- Rear end collisions appear to be the most significant type of motor vehicle-tractor accidents, and occur not only during hours of dusk, darkness and dawn, but also daylight hours in dry weather.

  -- Turning maneuver collisions also are prominent. (5.4).

- Equipment countermeasures have been developed for SMV farm tractors and implements of husbandry operating on public roads to provide adequate illumination and pre-warning systems such as front lights, taillights and reflectors, SMV visual designations, turn signals, and rearview mirrors. (5.5).

- Although the Uniform Vehicle Code, developed by the National Committee on Uniform Traffic Laws and Ordinances, comprehensively sets forth lighting and SMV recognition countermeasures, States have been slow to adopt new regulations. To date, wide variation exists among State laws and regulations governing SMV on public roads. (5.5; 5.6).

7.1.5 Accident Reporting and Records

- A need exists for an accident reporting system involving all types of farm equipment, including tractors:
  - -- Current data are inadequate in both scope and depth to identify in specific manner causes of tractor and associated machinery fatalities. Further, data on non-fatal injuries are virtually non-existent.
  - -- Such detailed data as exists are scattered among a number of agencies, universities, and other organizations.
  - -- Data elements are not uniformly collected and maintained. (6.0).

- Officials of the farm equipment industry, agricultural safety research agencies, farm journals, and recently-surveyed farm operators indicate support for a reliable farm machinery accident information system. (6.0).

- Information requirements necessary to meet objectives of a farm machinery safety program are extensive, requiring (1) accident survey requirements, (2) owner-operator reporting, and (3) on-scene reporting. (6.1).

7.2 Recommendations

In calling for a report on the agricultural tractor safety problem, including recommendations on means to prevent accidents and reduce the severity of injuries, section 8 of P.L. 91-265 requires that careful consideration be given to:

- The advisability of establishing uniform Federal safety standards in the design and manufacture of agricultural tractors sold in interstate commerce.
- Requiring the installation on such tractors of safety devices.
- Providing assistance to the States in developing accurate reporting procedures for accidents involving such tractors.

The following recommendations with respect to the Federal role in a Farm Machinery Safety Countermeasure Program, including agricultural tractors, are based on the results of a careful study of the farm tractor safety problem as presented in the preceding sections of this report.

7.2.1 Establishment of Uniform Federal Safety Standards is not Recommended at This Time

Federally-imposed agricultural tractor safety standards are not recommended at this time for the following reasons:

A. As highlighted in the findings of this study, significant advances in the design of tractors to improve safety in operations have been made over the past several years; e.g., in overturn protection, power takeoff (PTO) and hitch mechanisms, self-equalizing hydraulic brakes, and a lighting-recognition system. There is evidence to suggest that continued progress by the industry is being made to further improve critical safety elements and systems of tractors.

Safety standards for tractor overturn, PTO, and other safety hazard protection have been developed and updated, including field and laboratory procedures for testing tractor safety features, by ASAE and

SAE committees in which safety engineers within and without the tractor industry participate. For example, about 60 percent of the ASAE members are from industry, consultative and self-employed occupations, 20 percent are researchers and educators in universities, and 20 percent are Federal employees. (Appendix A:A146). SAE, in turn, develops technical standards through working committees whose members are selected on the basis of individual technical or professional competence. (Appendix A:172-3). FIEI, on behalf of the Industry Trade Association, through Engineering Committees, develops proposals for standards and submits them to ASAE and SAE for consideration. (Appendix A:A125).

Manufacturers of tractors and tractor safety equipment increasingly accept the SAE-ASAE standards as design guides. Research is carried on by individual companies, including both laboratory and field testing of safety features of tractors. Thus, the attitude of the tractor industry toward improved safety features on tractors and associated machinery is positive and progressive.

Lines of communication and action exist for developing, revising, and resolving technical issues of tractor safety standards. By way of example, the technical adequacy of one of the safety standards -- that relating to testing overturn protective frames -- currently is under question. Raised by the Chairman of the Nebraska Board of Tractor Test Engineers at the September 17 Public Meeting in St. Louis (Appendix B:B53-4;B60), the major issues were identified, discussed, and steps taken toward resolution of the issues at an October 23 meeting called by FIEI and attended by representatives of the University of Nebraska Tractor Test Laboratory, FIEI Engineering Policy Committee, ASAE Standards Committee, and tractor and farm equipment manufacturers.

B. While no data exist to identify the type, model, and age of agricultural tractors involved in fatal and disabling accidents, there is reason to believe that such accidents occur principally with respect to older tractors. Engineering improvements have been made over the past several years to make more safe the operating characteristics of tractors, to protect the operator from tractor overturn and from PTO accidents. Film strips of tractor testing by major tractor companies of overturn protective frames and cabs, taken to demonstrate the adequacy of such safety devices in protecting operators who remain in place during overturn, also indicate difficulties in actually overturning tractors because of other safety features.

C. The only potential safety standard for which an attempt at quantification of payoff can even be made at present involves overturn protection, and this payoff evaluation is limited to a single measure only -- that of fatalities -- and raises a number of questions.

Approximately 3.3 percent of the near-stable tractor population is replaced each year; that is, approximately 160,000 new tractors are marketed domestically each year with an equivalent number retired. If it is assumed that the involvement of new tractors in tractor operator fatalities resulting from overturn is in direct proportion to their share of the total tractor population, the requirement that henceforth all new tractors must have adequate overturn protection would theoretically save lives each year over a five-year period in the following magnitudes -- at an annual hardware cost approaching $50 million (assuming over $300 per tractor for protective devices):

Lives Saved By Tractor Overturn Protection
(All new tractors so equipped each year)

Year New Tractors Marketed	Years 1	2	3	4	5
1	9**	18*	18	18	18
2		9	18	18	18
3			9	18	18
4				9	18
5					9
Annual Lives Saved	9	27	45	63	81

* Calculated as follows: 900 (average annual fatalities) x 60 percent (overturn share) x 3.3 percent (new tractors' share) = 18 lives.

** New tractor fatalities reduced the first year, assuming new tractor sales staggered throughout the year.

However, the saving of lives in the indicated magnitudes by a Federal requirement that all new tractors must be so equipped must be discounted because (1) engineering analysis suggests that new tractors are safer than old tractors, and (2) an estimated 20 percent of new tractors currently are being marketed voluntarily with overturn protection and this percentage is believed to be increasing each year.

Thus, the need for careful payoff analysis is indicated, based on hard data to be obtained from a reporting system such as is proposed. This analysis should consider:

- Valid proof, based on actual accident experience that tractors are becoming safer, thus contributing to significant accident reduction.
- Specific causes of fatalities other than those attributable to tractor overturn.
- The magnitude and causes of serious and disabling injuries. At present, data is not sufficient to draw even the most tenuous conclusions.

The following actions are recommended, however, with respect to safety standards for new tractors:

- That the tractor industry redouble its efforts to market tractors that carry safety equipment as standard rather than as optional equipment.
- That the tractor industry intensify its efforts to promote continuous use of special safety features, including redesign of equipment where necessary for convenience of use. For example, PTO shields are taken off and discarded on the assertion that they are hindrances to connecting and disconnecting the PTO mechanism; overturn protective frames are removed for certain types of tractor use and then become forgotten safety aids.
- That the tractor industry voluntarily take immediate steps to phase out the sale of products that do not meet ASAE-SAE safety standards. For example, cabs and canopy frames are sold by tractor manufacturers and "will-fit" companies that are not overturn protective but can trap and crush the tractor operator in instances of overturn.

- That the insurance industry reasess its current practices in insuring farm operators against hazards, studying the feasibility of providing incentives for equipping tractors and associated farm machinery with safety features meeting existing safety standards. There is precedent for this already in automobile insurance as well as in the industrial safety area. Incentives of various types are already making their impact in the area of consumer protection.

- That the Congress, after a wait of two to five years from the date of this report, authorize a study of progress being made through concerted, voluntary effort to prevent the occurrence of, and reduce the severity of agricultural tractor accidents. At that time, if the engineering judgment indicated in this report as to the self-correcting nature of the problem proves not to be justified, uniform Federal safety standards should be required.

  Such a study will serve to provide a useful measure of the success of private industry efforts to reduce accidents and of the efforts of ASAE to accelerate

  > "the tempo of its activities to further improve agricultural safety. This is witnessed by the December 1969 commitment of the Agricultural Safety Committee to develop a plan for 50 percent reduction of agricultural accident fatalities by 1980. Further cooperation of all concerned parties for research on causes of accidents and education for safe operation can also help reduce tractor accidents.
  >
  > "If Congress decides that federal regulations are necessary to improve specific areas of tractor safety, then the technical meetings, conferences, committees, and cooperative standards activities of ASAE are available to consider feasible engineering solutions on which regulations could be based." (Appendix A:A150).

  The SAE also states their willingness ". . . to offer technical expertise and assistance in preparation of proposals for Federal Agricultural Tractor Safety Standards should the need for such standards be established." (Appendix A:A177).

7.2.2 A Federal Requirement that Safety Devices be Installed on Tractors is Not Recommended at This Time

It is not recommended that a Federal requirement be imposed at this time to require that safety devices be installed on all tractors-in-use. For example, even though in a recent survey the rollbar was the most widely recommended safety feature of farm operators who felt tractors need more safety equipment (Appendix B:B12), retrofitting of tractors with overturn protection is not recommended except on a voluntary basis because of design problems, costs, and difficulty in assuring compliance. For tractors more than ten years old (which account for some two-thirds of the current tractor population in the United States) the cost of the retrofit would approach or exceed the depreciated value of the tractor. A simple rollbar with seat belt costs from $195 to $450, and a cab providing overturn protection costs 10 to 15 percent of the cost of a new tractor. Further, overturn protection has not been developed for most tractors manufactured prior to 1963. Retrofit of models earlier than 1963 would require extensive alterations, including in some cases the redesign of the tractor rear axle housing.

The following actions are recommended, however, with respect to installing safety features on tractors already in use:

- That the tractor industry intensify its effort to market safety devices for tractors in use, including overturn protective devices for all tractor models where possible.
- That the tractor industry intensify its efforts to promote the continuous use of special safety features as indicated in the previous section.

7.2.3 A Federally-Assisted Uniform Farm Machinery Accident Data System is Recommended

It was noted in Section 6.0 of this report that many of the published reports reviewed with respect to agricultural safety indicate a need for a reporting system that would provide continuing scientific data on the extent, nature, causes, and severity of farm machinery accidents, including tractors, and the factors that serve to aggravate losses following the event. The need to establish a farm machinery accident reporting system has received almost unanimous support from all those who presented views at the St. Louis Public Meeting, including tractor industry representatives. In the preparatory stages of this report it was found that little information is available to determine the magnitude of the problem and that little understanding of the cause and effect of farm machinery accidents and injuries, and means of prevention, can be gained from statistics gathered principally from newspaper clipping services or files accumulated for other purposes.

Chapter Six presents an assessment of current methods of accident reporting and provides Recommended Program Guidelines for a National Farm Machinery Accident Reporting System. (6.2).

7.2.4 A National Farm Machinery Safety Countermeasures Program is Recommended

Several Federal agencies at present have responsibilities which directly affect agricultural tractor safety -- U. S. Department of Agriculture, Department of Labor, Department of Health, Education, and Welfare, and the Department of Transportation. There does not exist, however, a national farm accident safety program, nor is there an agency focal point for providing overview and coordination of agricultural tractor safety matters at the Federal level.

It is recommended that a National Farm Machinery Safety Program be established. The existing division of responsibilities within the Executive Branch suggests that the U. S. Department of Agriculture should be recognized as having prime responsibility in such a program, taking the lead in providing overview and coordination for all Federal agency efforts directed toward improving agricultural tractor and associated farm machinery safety.

Such a program should include the following activities, utilizing existing authorities and organizational channels to the fullest and supplemented with new legislative authority where necessary:

A. Establish a pilot national farm machinery accident reporting system sufficient to support the reassessment of progress two to five years hence which is recommended in section 7.2.1 which will:

- Provide for a central authority and repository for agricultural tractor and other farm machinery accident data.
- Provide financial and technical assistance to, and coordinate the collection of, accident data on both farms and public roads.

- Provide a basis for determination of the true magnitude of the tractor and farm machinery safety problem.

- Provide a basis for assessment of the need for further data collection.

B. Conduct rigorous analyses of the data produced by the pilot reporting system to identify the hazards of the tractor and associated farm machinery while operating in their environment. The results of these analyses, along with recommendations for eliminating or minimizing the effects of these hazards, should be identified and disseminated to ASAE-SAE committees, NSC and other organizations, to the farm machinery industry including sales and service outlets, to responsible Federal and State agencies, to land-grant and other colleges and universities, to vocational agriculture teachers, to farm organizations and the farm population.

C. Bring Federal agency authorities, research and program activities to bear on the problem of farm machinery health hazards such as those associated with excessive noise, fumes, dust, vibration, and other aberrations referenced in Section 3.3 of this report.

D. Undertake or encourage the undertaking of a comprehensive analysis of the task of tractor and associated machinery operations, not only for better tractor and safety systems design to match operator capabilities, but also to provide a better base for training programs.

E. Assist educational and training channels already established to:

- Improve the effectiveness of courses of instruction and training by incorporating results gained through operator task analysis and through industry and university research efforts.

- Develop guidelines and carry out courses for instructors of training courses.

- Develop and carry out remedial and refresher training programs.

- Provide for a broadbased educational effort to reach the farm population with information on tractor accident and injury avoidance.

F. Develop and issue fact sheets for the farm and non-farm population of highway drivers, providing information on farm machinery characteristics when operated on the public road recommended to States for inclusion in:

- State driver manuals.
- State driver's license tests.
- Driver education programs.

G. Through coordinated agency action, develop appropriate procedures to preclude the Federal purchase of agricultural and public road maintenance tractors which are not equipped with maximum operator safety features, and study the feasibility of adequately retrofitting tractors in use. Request Governors to take similar action for State-owned tractors.

H. Develop a "safety package" for tractors operating on the highway, and recommend to the States that legislation be enacted requiring this package for all tractors moving on public roadways. This package would include:

- Illumination systems for tractors operating on the public road at night.
- Rearview mirror systems to permit 360 degree visibility for the operator.
- Systems to provide 360 degree positive recognition of the slow moving vehicle by the motorist at a safe distance to permit proper speed differential adjustment both day and night.
- Turn signal systems to provide 360 degree display of planned operator maneuvers.

I. Recommend to the States that:

- A valid driver's license be required for operating a tractor on a public road.

- Farm tractors generally be required to comply with State rules of the road.

J. Follow-up on recommendations set forth in the preceding Sections 7.2.1 and 7.2.2.

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APPENDIX A

TECHNICAL PAPERS

Invitations were sent to eight organizations and to six individuals, inviting them to prepare a total of sixteen technical papers on eight different aspects of agricultural tractor safety. Some duplication was planned purposefully; e.g., four different papers were invited on the subject of agricultural tractor design, three papers on safety standards for agricultural tractors, and two each on power takeoff units and the training of agricultural tractor operators. The Bureau's purpose in this planned duplication was to assemble the latest thinking of individuals with acknowledged expertise in these areas. The invitation of sixteen previously unpublished technical papers from fourteen different sources was designed to get the latest research findings and thinking on specific subjects from organizations and individuals who have demonstrated competence in specific areas of agricultural tractor safety. In the letter sent to the Farm and Industrial Equipment Institute (FIEI), the Safety Program Coordinator of that organization, which represents the tractor manufacturing industry, was invited to have papers prepared on the subjects of: (a) safety standards for agricultural tractors, (b) power takeoff units, and (c) agricultural tractor design. These papers were prepared by personnel from within the tractor industry. Fourteen papers or letters were received.

Several of the technical papers submitted included exhibits or appendixes. In these exhibits and appendixes, some writers included copies of ASAE or SAE standards, tentative standards or recommendations. These standards and recommendations are not reproduced in this report, since they are readily available in the 1970 yearbooks of the American Society of Agricultural Engineers and the Society of Automotive Engineers, Inc. Other exhibits or appendixes that were submitted, but which are not reproduced in this report, are noted in the reports to which they are appended.

The papers in Appendix A appear in the general order in which the subjects are discussed in the report.

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TRACTOR DESIGN AND ITS RELATION TO SAFE OPERATION

by

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Prepared at the request of the Department of Transportation for their use in reporting the farm tractor accident problem to the congress.

Summary

This report gives a review of tractor design from the first tractor to the present time. Suggestions are also made on improvements that can be made in future design.

Tractor Design and Its Relation to Safe Operation

"The story of power farming is the great saga of our times. It is a story of free enterprise, perseverance, and endurance of the individual of vision, idealism and cooperation among men. Of the lightening of human toil and the release of millions of workers from farms to feed the ever hungry industrial revolution. By no means least, it is the story of producing food necessary to feed a burgeoning population both in this country and abroad."

This is an excerpt from a paper given by Wayne Worthington, a Consulting Engineer at the Farm Construction and Industrial Machinery meeting in Milwaukee, Wisconsin in September, 1966. In the paper titled "Fifty Years of Agricultural Tractor Development"5/, Mr. Worthington comments on the development of the tractor. It is well to examine many of Worthington's quotations in regard to the evolution of the farm tractor as we know it today.

He pointed out, "the term 'tractor' first appeared in U.S. patent 425600 issued on a self-propelled gasoline engine constructed by George H. Edwards of Chicago. Its first use in advertising was by Hart Parr circa 1906. It is now employed throughout the English and Latin speaking countries. True to their traditions, the Russians took over the phonetic term without change and claimed the tractor as their own invention.

In 1903 the first Hart Parr tractor was marketed, and for many years theirs was the world's largest exclusive tractor factory. A rash of three wheeled tractors followed, violating all of the yet unknown laws of stability; and properly died aborning.

Not until the first Winnipeg Industrial Exposition in 1908 were competitive trials conducted which allowed the public to compare the performance of steam traction engines and gasoline tractors. These trials continued yearly through 1912, in spite of a rapid decline in their popularity and acceptance of steam power. A great scramble ensued by manufacturers to salvage their trade position by business acquisitions and consolidations. As late as 1920 15 companies manufactured steam traction engines and in that year produced 1,776 units.

In 1911, Hart Parr shipped three trainloads of tractors to the great plains of western Canada. Farmer interest was at a fever heat as millions of acres remained unplanted due to lack of animal power. In 1911 a national tractor field demonstration, sponsored by the Farm Press, was held near Fremont, Nebraska. In 1912 the Rumely Company shipped two trainloads of oil pull tractors to Winnipeg, Canada.

Mr. Worthington did a good job in listing the sequence of changes that took place in the early tractors. He noted that the Moline-Universal general purpose tractor was the first widely exhibited and promoted tractor to receive great acceptance. This machine was characterized by articulating front and rear sections. The front section comprised power plant, power train, and two drive wheels. The trailing rear section with integral drawbar, included the driver seat and controls and was supported on two wheels at the rear. Implement attaching points with necessary cultivator clearance were provided amidships for attaching integral cultivators and other tillage tools. The operator had a view downward on the shovels but forward vision was obscured.

Perhaps the tractor that drew the greatest amount of interest was the Fordson tractor. When this one was first marketed, sale was restricted to the federal and state governments. However, by August 1920, Ford claimed the sale of 100,000 tractors. Unfortunately, the design of the Fordson tractor flagrantly violated all principles of stability and many fatal accidents, primarily rearward upsets, occurred. A change in the hitch helped solve this problem. Today, of course, rollbars would also help to alleviate this problem.

The next major event in the development of the tractor was the Nebraska Tractor Test, under a law enacted by the Nebraska State Legislature. The purpose of this act was to "provide official test for gas, gasoline, kerosene distillate, or other liquid fuel traction engines in the State of Nebraska and to compel the maintenance of adequate service stations for same."

One of the purposes of this test was to assure that a tractor was capable of running for at least 10 hours. In some situations, farmers had purchased new tractors and the tractors would run for only a short period of time. The University of Nebraska was designated to conduct the official test and the State Railway Commission of the State of Nebraska was charged with administerming the bill and issuing licenses to manufacturers to sell within the state.

In June of that year a call was issued to all tractor manufacturers to participate in discussing these tests and cooperate in their conduct. The benefits of the Nebraska test and its impact on the farm tractor industry cannot be overstated. Its effects have been world-wide.

In referring to tractor testing, Mr. Worthington noted that the decade starting with 1920 was one of elimination and consolidation in tractor manufacturing firms and models. Tractor testing at the University of Nebraska started March 21, 1920 and Waterloo-Boy was the first model on which tests were completed. A total of 69 tractors were tested that year although others were entered which were unable to complete tests due to mechanical failures. The Nebraska test of 1920 revealed glaring engineering deficiencies as well as outstanding refinements.

As an example of the latter, the governors of one manufacturer's tractor held speed variation from no load to maximum load to 4.82%---a degree of performance never since bettered. Those few tractors incapable of adequate performance disappeared from the scene within four years. Shortly after World War I the price of tractors declined tremendously. The Fordson tractor price dropped to $395, a cost equal to about 11 cents per pound based on the weight of the tractor.

In 1923, only two years after the directors of Deere and Company had considered abandoning their Waterloo tractor operation, they started production of their famed Model D tractor.

This tractor was powered with a slow speed 800 rpm 2-cylinder engine capable of operating on a wide variety of fuels. This was a noisy tractor. The operator's position was low and he was subjected to much dirt and dust. Forward vision was poor. The exhaust was practically unmuffled and plagued the operator with fumes and smoke. The seat was a steel stamping, supported on a rigid flat steel bar.

But the tractor was low in cost, durable and economical to operate. It started readily and was easily accessible for repairs and thoroughly dependable. It introduced power farming into extensive areas where tractors had heretofore failed to penetrate. The Model D tractor was successfully modernized in keeping with progressive engineering developments and enjoyed a production life of 25 years. During the depression era the production of tractors was extended to the development and refinement of the power unit.

The first significant change in tractor design during this period was the appearance of the Oliver Hart Parr general purpose tire tractor with tiptoe drive wheels. These spoke steel wheels had narrow rims supporting staggered high cast iron lugs. In 1932 several tractor manufacturers were experimenting with low pressure tires having a nearly circular carcass configuration similar to that of the current motor truck tires. At Big Rock, Illinois a tractor equipped with pneumatic drive wheel tires literally stole the show.

At about the same time research work with rubber tires was being initiated at the University of Nebraska in cooperation with four of the leading tire manufacturers. During these depression years tractor and tire manufacturers alike were desperate for any innovation which would help sales. In 1933 pneumatic tires were moving toward acceptance by tractor manufacturers and the tire manufacturers started to aggressively promote sales through their own outlets encouraging field conversion. By 1934 one leading tractor manufacturer offered rubber tires as standard equipment, all others provided them as optional equipment. In tests conducted throughout the country rubber tires were found to effect an increase in tractor drawbar power.

One innovation that took place prior to this time, in about 1923, was the development of the row crop tractor. This was developed by International Harvester and enabled a tractor to travel through high growing crops. In 1936 the first rear mounted hydraulic rock shaft power lift was placed in production. This eliminated the structural and operating limitations inherent to the earlier mechanical power lifts and made it possible to handle a new generation of heavy duty deep tillage tools and four row planting bedding and cultivating equipment.

In 1938, Harry Ferguson, an Irish inventor, introduced what is known as the 3-point hitch. This was not entirely a new concept since patents show that Andreas Mechwart, an Austro-Hungarian, made such a unit in 1890. Harry Ferguson succeeded in convincing Henry Ford of the merits and possibilities of the implement attaching, lifting and control system. As a result of Henry Ford's enthusiasm, the Ford tractor with Ferguson system came into being and was placed on the American market in 1938. The Ferguson system not only helped in the placement of extra weight on the rear wheels for better traction but it also helped to cut down on the possibility of rear overturns.

Since the Ferguson system was introduced in 1938, a number of refinements have come about in the use of the agricultural tractor. For a number of years, the tricycle or row crop tractor was very prominent. This type has now given way to the wider front end models which now predominate on agricultural tractors.

The machinery industry has done a lot in the past to make tractors more safe. One of these has been the development of the roll gard. The roll gard was developed by Deere and Company in 1965, and information was released that year on this protective device. In July of 1966, the public first had a look at the roll gard in an overturn demonstration at the Nebraska Tractor Power and Safety Day. Two tractors identical in make were overturned by running them off a roadway. One tractor had a roll gard protective canopy. People could imagine the horrible impact had a person been riding on the tractor without the protective canopy since it overturned 180°. The unit with the protective canopy went only 90° and was kept from completely overturning by the roll gard.

International Harvester followed later that year with a roll over protective device. All of the major manufacturers now have the roll bar and protective cabs or crush resistant cabs. Some are still in the developmental stage, however, protective devices are available for some models of tractors made by the tractor manufacturers. Some manufacturers have the roll over protection available for all of their models.

Manufacturers began to place lights on tractors in the early 1950's for operator safety. A number of safety devices such as shields for the power take off and other parts of the tractor have been developed. Perhaps the weak link in the power shielding and protective devices comes from our short line manufacturers. The major manufacturers do a good job of shielding their equipment, but many of the short line manufacturers are not knowledgeable of the codes and recommendations set up by the American Society of Agricultural Engineers and the Farm Industrial Equipment Institute. Some effort must be used in acquainting these people with such standards and requiring that they follow the codes and recommendations of ASAE and FIEI members.

During the last 20 years the hydraulically controlled systems for trail type farm equipment and for mounted equipment have made the tractor an even more useful tool for the farmer. This is also a safety feature. The farmer does not have to move the tractor levers or move equipment up and down by getting off the tractor. The controls are of a console type at his fingertips.

Power take off drives have been made much safer. The power take off cover is no longer the inverted U trough that was so common in our early tractors. With the revolving power shield, the shield turns as the power take off turns. If someone touches the shield, the shield stops and the shaft is allowed to move as before.

A look at other safety features of tractors since 1940 include:

1. power steering
2. power brakes as regular equipment
3. a quick coupler which makes hooking up of equipment much safer and reduces the amount of jockeying required to attach implements
4. an uncluttered platform
5. PTO shielding and rotating shields in most implement power lines
6. shroud and shielding of the fan and alternator
7. adequate steps and handholds for safe mounting and dismounting
8. a fuel tank location which keeps the fuel cooler with less danger of splashing fuel on hot engine while fueling
9. fenders as standard equipment
10. safety interlocks to prevent starting in gear

11. an ether starting unit for use in cold weather

12. a control location designed to eliminate finger pinching and reduce effort in movements

13. adequate lighting for visibility plus flashing warning lamp and rear lights and shielded instrument lights to reduce glare

14. use of hydraulic system to eliminate manual lifting by use of attachments

15. a provision of front and rear weights when required for stability

16. a power shift transmission which will hold on downgrade in all gears, no free wheeling

17. a positive park lock

18. adjustable seats or controls

19. protective knobs on all hand controls, non-skid surface on all foot controls

20. screens to prevent accumulation of trash around heated areas

21. the operator's manual with complete instructions and safety warnings supplemented by decals on the tractors

22. cigar or cigarette lighter with circuit breaker which permits lighting up with hand on wheel

23. horns on some tractors

There are other features that also contribute to safety. One of these is that the safety canopy is designed such that it can be used with other implements. The canopy can have an enclosure for foul weather working.

Much work has been done on reducing tractor noise by reduced noise level mufflers. This also includes improved visibility due to the revised muffler and vertical air intake. Seatbelts are standard equipment wherever roll bars are used. An additional front ballast will be available to improve the stability with heavy rear mounted implements.

We should also look at one other area that has received a great deal of impact. In 1963 Ken Harkness of Ohio State University worked on the development of a slow moving vehicle emblem for slow moving equipment being used on the roadways throughout the United States. This emblem is now recognized and required by law in 26 states of the United States. Five Canadian provinces also require use of the SMV. Dramatic cuts in accidents and fatalities have been shown in those states where the SMV is required on equipment. Most manufacturers are aiding in the dissemination of the emblem by placing the decal on their equipment or placing the keystone bracket to receive the mounting bracket of the slow moving vehicle emblem.

We should be aware of this continuous stream of new ideas. This shows in the fact that in about 1967 added interest was placed on the noise level of tractors. Much more time, money and energy will be spent before the problem is completely solved but the tractor design engineers recognize the problem and are attempting to alleviate it. Noise level testing is also a part of the Nebraska Tractor Test Code. This new development started in 1970. For a more complete view of the tractor development and design for 1919 to 1970 I refer to exhibit A, The Agricultural Engineering Journal, September, 1970, Volume 51, No. 9, pages 514 and 515, titled "Fifty Years of Nebraska Test Highlights."

From the beginning of tractor usage there has been the problem of tractor accidents. The main problem with the steam engine was its excessive weight and weak bridges. Many accidents occurred when the steamers would go over wooden bridges that were not capable of holding the weight of the tractor. These overturns, then, were a result of a failing bridge toppling the steamer into the ravine.

Speed was not a major problem. It was not until the Fordson tractor came on the scene that the overturn problem really came into being. Not too many side overturns happened with the older steel wheeled tractors. In the case of the Fordson tractor, most of those were backward overturns and these were the result of an improper hitch. Harry Ferguson worked with the Fordson people on a 3 point hitch in an attempt to put more weight on the rear wheels and cut down on the rear overturn. Added to the backward overturn of the earlier tractors was the lack of proper weight on the front of the tractor. Clutches jumped and would not ease the tractor forward slowly. Lug wheels would not give any slippage also added to this problem.

With the advent of the rubber tractor tire, a new roll over problem, the side overturn, was created. The rubber tire hitting an object such as a rock or washout would often develop enough energy to overturn the tractor under specific conditions. Even today the side overturn occurs about 4 times as often as the rear overturn according to a study conducted by Schnieder and Florell from Nebraska.[2/] Similar findings were uncovered by Willsey and Liljedahl of Purdue University.[4/] Not only did the rubber tires encourage the side overturn, but excessive speed, the tricycle tractor and improper weighting also increased the number of side overturns.

Perhaps the only place where side overturns have been decreased is the situation where dual tires are used on the rear of the tractors. This cuts down on the number of side overturns but increases the number of rear overturns due to the extra traction which is obtained by the dual tires.

The stability of the tractor is dependent on a number of things. The tricycle type tractor will overturn more easily than the wide front end tractor. However, many things must be taken into consideration because under certain conditions the wide front end tractor can overturn just as easily.

The National Safety Council assumes that 1,000 people are killed yearly in tractor accidents with approximately 600 of these from tractor overturns. During their work on the roll bar, Deere and Company assumed that there was one fatality for each 9300 tractor operators. This was based on a population of approximately 4,800,000 tractors in the United States. It is interesting to note that in those states where an effective safety program is conducted that the number of fatalities is significantly lower. A good example of this can be shown in Nebraska where the fatality rate averages approximately 15 fatalities for every 100,000 tractors. Compare this to the national figure of 22 per 100,000 tractors and note the reduction of 7 fatalities per 100,000 per year. Nebraska, with a tractor population of 200,000 tractors, shows a saving of 14 lives per year.

Speaking of stability, there are so many variables that can be thrown into any one accident that it would take an extensive document to list all of the different possibilities. This is why it is important that people be trained to know how to properly load and use tractors. For example, in the study conducted at the University of Nebraska, we found that tractor overturns for those under 20 years of age occurred because of excessive speed.[2/] These were usually speeds of 15 miles per hour or more. For those over 50 years of age, the main cause of accidents was attributed to driving on too steep an incline. In many situations the tractor was being used for a purpose for which it was not designed, such as getting cattle or as a method of transportation. In some situations the tractor operators were drunken drivers who had lost their licenses and were driving a tractor as a mode of transportation. In only 34 of the 100 cases, the tractor was being used in the area for which it was designed. In the other 66 cases the tractor was being used for transportation on county or state highways or farm roadways.

At the time of this overturn study in Nebraska nine of the overturns involved tractors where a roll bar or cab was in place. All nine people lived. In only one situation was the cab considered to be a crush resistant cab. The others were ordinary cabs but they still saved the individual's life. A continuation of this study shows that seven more overturns occurred between January 1, 1969 and the current date. In these additional seven overturns a cab was in use and all seven operators are alive.

One problem we are now seeing is that some companies are calling their cabs crush resistant without testing the cabs according to ASAE recommendations S306.2, S310.1, S336, S305.2. This is evidence of the situation which I mentioned earlier where the short line companies are not knowledgeable of the codes and recommendations set up for testing of various parts of the tractor, such as shields or cabs. The eight major manufacturers do have crush resistant cabs. With the development of the roll bar and the crush resistant cab, we also accentuate the noise problem. Many companies are working to cut down on the noise trouble by properly insulating the cabs and roll bars so that noise levels are brought down to a working minimum.

Braking Systems

In the early 1960's two manufacturers came out with power brakes for tractors. At first there were some corrections that needed to be applied to these brakes. However, with continued refinements the braking systems on most agricultural tractors are good. The problem of braking occurs predominantly with trailing equipment. A good example would be the large machinery trailers or anhydrous ammonia trailers. We must realize that some of the towed equipment such as the anhydrous ammonia tank might weigh close to 8,000 lbs. If these do not have braking systems and must be stopped immediately, jackknifing can occur and result in overturning or a more serious type of accident. Many of the tanks that are being made lend themselves to this type of overturn since they might also be 3 wheeled tanks or a tricycle type tank. A good alternate braking system should be devised and made as standard equipment on many pieces of farm equipment coming out in the future.

There are some suitable alternate braking systems available. Possibilities would be to plug the braking system into the hydraulic unit of the power unit. One other possibility is to have electric braking. Another possibility is to have braking set up on the unit hitch. When the unit starts to come forward the brake takes over and slows the unit down. Once again, this gets away from the major manufacturers and gets back to the short line manufacturer who is developing the trailers and tanks. We cannot condemn the major manufacturers, however, the problem occurs when we have the short line manufacturer not doing his job.

Suspension Systems

Before 1923 most tractors were of the wide front end type. In 1923, International Harvester came out with the all purpose row crop tractor, or the tricycle tractor as it is more commonly known. The tricycle tractor has limitations particularly on steeper hillsides. However, for row crop use it does have definite advantages. The tricycle tractor had great prominence until the middle and late 1950's. At that time there was a move back to the wide front end tractor. We must keep in mind that wide front end tractors will overturn the same as tricycle tractors.

Stuckey of Ohio State University conducted a study of 406 tractor overturns in which 204 of the tractors were wide front end and 202 were tricycle front end.[3/] A similar study conducted at the University of Nebraska by Schnieder and Florell showed that 67 of 100 overturns occurred to tricycle type tractors.[2/] Keep in mind that in both of these states we do not know the population of the wide front end tractor in comparison to the tricycle tractor. Without these figures we cannot tell if there is a greater number of wide front ends in the state of Ohio or Nebraska. Consequently, we would expect more overturns from this type of tractor. In many situations, special type tractors have been built for special purposes. Road maintenance crews use a tractor with a low center of gravity and low suspension. This cuts down on the probability of tractor overturns. Tractors do have a high center of gravity in order to go over tall growing crops.

However, we should not condemn the manufacturers for the great amount of overturns. We must also look at some other aspects of construction. Many of our conservation dams or terraces are made with excessive slopes. These may be in the neighborhood of 3 to 1 or even 2 to 1. The same holds true for impoundments such as farm ponds which are constructed by assistance from the Soil Conservation Service and other federal or state agencies. Many times they will design a structure with a 3 to 1 slope and then turn this over to the farmer to maintain for the next 50 years. This means that he might be mowing this area with a tractor that will tip over at from 30 to 40 degrees. The structure will have a slope of some 26 to 30 degrees. The slightest bump or depression which is hit by the tractor tire might cause the tractor to go over. Therefore, the tractor cannot be blamed for the accident. We also must realize that the farmer causes some of his own problems. He may have 3 or 4 tractors on his farmstead. Any one of these tractors might be an old tractor and relegated to doing one specific job. If he places a front end loader on a narrow front end tractor and does not counter weight it properly, he can be asking for trouble.

The development of a good suspension system can be a nightmare for the manufacturer. He must develop a system that is capable of a wide range of situations. A farmer may take a tractor and hook an eight row mounted planting system onto a rear tool bar. He might put tanks forward capable of holding two or three hundred gallons per tank. This would equal out to about a one and a half ton weight. The rear wheels must be capable of carrying the added weight to the rear. The hydraulic lift unit must be capable of raising and lowering this. The front tires must be capable of handling the excessive weight of the liquid in the tanks. Power brakes must be capable of stopping the tractor in the event of a needed stop, and the gear train must be capable of withstanding the forces applied to it. This becomes a design problem for the engineer and an education problem for the manufacturer, for the dealer, and for the University personnel who work with the farmers.

Hitch Point

The design engineer does a good job of determining the point of pull or center of pull in the tractor as it leaves the plant. If the tractor is used as designed to be used we would not have too many rear tractor overturns. Hitch point is designed to pull through the center of pull. If this is not done, backward overturns can occur.

Occasionally an operator hitches to the 3 point hitch rather than to the drawbar. If the 3 point hitch is raised we have a situation very similar to hitching to the axle and pivoting around the axle. We have seen other situations where the operator thinks that if he hooks to a point forward by the rear wheels and pulls backward under the tractor that he cannot overturn the tractor backwards. This is a fallacy. If the chains or cable are not kept low, the tractor can pivot around the axle and once again the tractor can go over backwards. Even the 3 point hitch with mounted equipment is not an entire safeguard if the operator does not use good common sense. We know of some situations where the linkage bars have been broken when the tractor came over backwards and the operator was pinned between the mounted equipment and the tractor itself. Proper hitching is also dependent on a good hitch pin, where trailing equipment is used. Many accidents have occurred where the hitch pin has sheared or where it has been bounced out of the hitch as the tractor goes over rough ground. In other situations the hitch pin has shot forward during the shear. Operators have been hit by the pin. We have illustrations where cabs have saved the operator from serious injury when improper hitches have been used. We must realize that the problem of hitching has come a long way since the first tractor was developed. The development of the 3 point hitch has saved many, many lives that would have resulted in backward overturns had it not been for the 3 point hitch.

Power Plant

Throughout the history of the development of the internal combustion engines we have had engines that have worked properly for many years. Today on our American farms we can see tractors 30 to 40 years of age being used daily or in many situations as a second or backup tractor. With demands for increased power we have had to go to bigger engines. When this is done we come to added weight problems and added noise problems. The trend is also to get the most horsepower obtainable for the fuel that is used. Many of the early engines had updraft carburators whereby the carburator would take air in at an area quite close to the ground. There was no type of filter to filter out the dust. Problems occurred whereby the engines would be ground out in a short period of time. Later on, filters were used to filter the air going into the engine. Back exhaust was used on some engines contrary to the top exhaust that we now have. More explanation follows on this subject. Overall, we would have to say that the power plants of our tractors both past and present have been of good design.

Human Engineering

A new term, human factors safety, has come on the farm tractor scene in the last few years. From the advent of the first tractor to the middle 1960's the tractor was designed for a specific job. Operator safety was not kept in mind. This can be seen in some of our earlier models such as the Model D where the tractor had a stamped seat which set on a four inch by one-half inch spring bar. This was the only comfort for the operator.

One physician noted that approximately five out of six farmers he had treated had a symptom known as tractor drivers disease where the back has some damage as a result of being joggled around on the tractor. In the middle 1960's some of the major manufacturers worked on the development of a more comfortable operator's seat.

A few years ago the author contacted 52 of the Agricultural Engineering Departments in the United States and Canada to find out if they had any safety courses or human factors courses in their engineering curriculum. Some of the departments had safety courses, however, they could not give a good explanation of their thoughts of human factors in engineering. Forth and Roll of Deere and Company conducted a study with other manufacturers to investigate safety and human factors engineering. It was interesting to note that 83% of the manufacturers contacted thought that students should have some human factors courses at the universities where they took their training. Eighty-three percent also thought they should have safety courses at the university where they took their training. Again this points out that human factors engineering and safety are similar in people's minds.

We do have one problem in human factors engineering. We have the engineer who is machine oriented and does not know as much as he should about the human body. We have the human factors engineer who knows the function of the body but does not know the function or the purpose of a machine. At the present time there is an attempt to wed these two agencies in order to use the expertise of both in the development of machines to lessen man's work.

As we look to the future we can see many problems where human factors engineering should take place. Noise level is one good example. Attempts are being made to produce quiet equipment. This covers a multitude of noise making systems since the transmission, the engine exhaust, engine clatter, fan noise, turbo-charger noise, all have to be considered. We are also attempting to improve the environment in which the operator works. With a crush resistant cab he has the protection of the cab. With a filter system we can filter dust, pollens and molds out of the air that he breathes. With an air conditioning unit the operator can work in comfort during the summer. With a heater he can work in warm surroundings during the winter. The operator is also protected from the rays of the sun, cutting down on the incidence of lip cancer. Those who are affected by allergies such as pollen, by bee or insect stings are also able to work in the comfort of a protective cab. The operator is also protected from hydraulic hose breakage, from anhydrous hose breakage, or from flying material which might break from equipment as it is being put under heavy stress. Figure 1. Seats are being improved for operator comfort. Controls are placed at fingertip length. Steering wheels are being made so that they may be adjusted to the size of the operator. Power steering reduces the amount of energy a man must exert. Tinted glass can cut down on the amount of sun rays that the individual receives. These are just a few of the benefits of design that are occurring at this time. Some of the plans for the future are quite intriguing. I look forward to great advancements in our tractors of the future.

Fuel and Exhaust Systems

There is still a lot of work that must be done on the fuel and exhaust systems. Great advances have been made in the past five years; however, prior to this time, there were many accidents as a result of fires from the fuel system or accidents that were caused in an overturn situation. Each year we have numerous fires as a result of fuel tanks running over or being improperly fueled. These fires can be the result of a static spark, a hot exhaust, or an open spark in the ignition system. In many situations the fuel tanks on older tractors are situated so that the heat from the engine comes past the fuel tank. Reports have been received where the fuel in the tank was boiling because of the excess heat given off by the tractor engine.

The placement of the fuel tank also has effect on the center of gravity of the tractor. This can be quite advantageous, but the operator must be aware of the advantages of this system. On some tractors the fuel tank is located forward. This means that when the tank is full, they have a ballast of approximately 240 pounds forward of the engine. In most cases this is even forward of the front tires. This serves to cut down the possibility of a backward overturn. Conversely, a tractor with the fuel tank behind the operator has the advantage of extra weight for added traction when the tank is full. This, however, can be detrimental if the operator gets on too steep an incline and the added weight to the rear of the tractor moves the center of gravity to a point back where the rear wheels are in contact with the roadway. In this situation, we have a backward overturn.

Diesel tractors give very little problem from a fire standpoint. However, the LP gas or the gas tractors do present problems when the tractors are being fueled. Our recommendations are that the tractors be fueled just prior to the time when the operator goes to the field. If the operator comes in on a warm summer day he should not fuel the tractor until he is ready to head back to the field after dinner. If he fuels prior to his lunch period, the fuel can expand and some might run over the engine. This can cause a fire if conditions are right. Much can be written about the limitations or advantages of the various fuels. Time does not allow me to include the information in this paper.

In regard to exhaust systems, there is merit as to the proper placement of these systems. An exhaust too close to the operator submits the operator to excessive noise and fumes. Most cab manufacturers have an exhaust extension that will exhaust the burned gases over the top of the cab. Without this extension, there is excessive noise and the exhaust gases can have an effect on the operator. The direction of the exhaust system is also of prime importance. Engineers at South Dakota and Nebraska did considerable work on the placement of mufflers and the directions of the muffler outlet as it relates to the noise that a human encounters. Placement of the exhaust might also have an effect on the horsepower of a tractor. In a test at the University of Nebraska - Tractor Testing Laboratory - one particular tractor with an exhaust under and to the back of the tractor, showed a decrease in horsepower when the wind was coming from behind the tractor. This loss of horsepower was traced to the fact that the burned vapors were being transported forward to the tractor and the tractor was taking in some of the exhaust gases that had emitted. In this way pure air was not taken into the carburator. Consequently, there was a reduction of about three horsepower as a result of misplacement or improper placement of the exhaust.

The manufacturer can make the tractor much quieter than it is. We must remember, however, that some noise is necessary for the operation of a tractor. We must also realize that we have a lot of work to do in changing people's attitudes. For years people have thought that a tractor should be noisy, it should belch out smoke, the wheels should spin, the tractor should roar; in short, sound and look like the beast it was meant to be. We are quite successful, I believe, in changing people's attitudes. People now are selecting tractors for both comfort and convenience plus the job that they are designed to do.

Seating and Passenger Accommodations

A great deal of work has gone into the betterment of the seating arrangement for the farm tractors. Many of the major manufacturers have given great amounts of energy, time and money in the development of a good seat for the operator. Some companies have gone so far as to isolate the operators platform from the rest of the tractor. This not only gives a smoother ride, but it also gives the benefit of less noise since the noise cannot come up through the rubber mountings which the platform is set on. Regarding passenger accommodations, the U.S. manufacturers do not look on the tractor as a mode of transportation. Some of the foreign countries, however, have buddy seats on their tractors and do use the tractor as a method of transportation. We try to discourage extra riders on tractors as much as possible. We are not critical of extra riders when there is a cab to hold the individual inside. Most of the fatalities to extra riders happen to very young people who cannot hold on and fall from the tractor and are consequently run over by trailing equipment. The manufacturers have made good fenders available to the operator. These fenders have good hand holds on for mounting and dismounting from the tractor. One manufacturer does have a place where an operator can sit and hand holds are available. We must keep in mind, however, that the farm tractor is designed for one purpose and this is to till the soil. It is not designed as a passenger vehicle.

Maximum Speed

The maximum speed of the farm tractor in most cases is too fast. Some models are capable of going at speeds up to 22 miles per hour. Fifteen miles per hour is fast enough. The only place where the 22 mile per hour speed is used is on transportation from one area to another. The difference of a few miles per hour will not make a big difference in moving time from one field to another, but it might mean the difference between life and death. Speed of tractors was a factor in the study conducted by Schnieder and Florell of 100 Tractor Fatalities.[2/] In this situation, young people were involved in accidents where speed in excess of 15 miles per hour was a major factor. A tractor going on a graveled or dirt roadway begins to bounce if speeds are too fast and the front end does not have good contact with roadway. When this occurs, it is easy for the tractor to go out of control.

One other hazard in high speed operation is the gravel pile along the edge of the roadway. Many overturns have occurred where the rear wheel of the tractor was run into the gravel pile. This would pull the tractor into the ditch and the tractor would overturn. Once again, excessive speed leads to this problem. Some tires have ballast in the rear tires. This can be calcium chloride, other liquid solutions or it might be a barium powder mixture. If a tractor goes too fast, this material starts carrying over with the tire rather than seeking its own level. When this occurs, the tractor can begin bouncing and jumping and control can be lost.

Coasting out of gear is another problem that leads to accidents. Many states have laws providing that a vehicle shall not be allowed to coast downhill with that vehicle out of gear. A tractor with equipment behind can reach a fast rate of speed if the incline is steep enough. Even though we have a law forbidding this, it still occurs.

Security of the Vehicle

Most of the new farm tractors have the safety lock switch, and as a result, few acts of pilfering occur. Tractors are damaged, but it is usually the type of damage where the engine is not started. Most companies do have a key that will fit the general line of their model of tractors. Therefore, anyone with a certain type of key could start the particular makes of tractors. In fact, some of these will start other makes of tractors. The problem of stealing a farm tractor is minimal. The problem of damage if the tractors are allowed to sit in the field is greater. This is not a manufacturer problem but one of the individual operator.

Conclusion

Generally speaking, the farm tractor manufacturers have demonstrated significant improvement in the development of the farm tractor. This is evident when one looks at the list of achievements on pages 514 and 515 of Exhibit A. Much more has to be done, however.

Human factors engineering is of major importance. The engineer must develop a tractor to do a job. At the same time, he must consider the comfort and health of the operator.

Testing must be done to prove the benefits of safe equipment. Not only must we do testing, but we must also make people aware of the improved design and safety features on our tractors. Figures 4, 5, 6, 7 show actual tests being demonstrated as part of the Tractor Power and Safety Day program. Sixty-five thousand people have witnessed these demonstrations on protective cabs since 1965.

Land grant universities have the obligation to bring this story to the people within their states. Only a few states have a safety program where they bring this information to the farm people. County Agents, Vocational Agriculture Instructors, implement dealers, have been an important segment in telling the story, however, these have not functioned in all states.

Perhaps the most glaring weakness of overall equipment design is the ignoring of proven standards and recommendations by many of the small manufacturers. Until they design and build their equipment with safety in mind, we will continue to have accidents. These definitely reflect back to the tractor since most of the machines are powered by a tractor. The standards are available, it's up to the manufacturer to make use of them.

The tractor manufacturers have the problem of coping with the noise problem. Vibrations fit into the same category since like noise, they can lead to fatigue.

Exhaust vapors also have an important place in future design. With our added emphasis on air pollution, it is increasingly necessary that exhaust emissions be as free of toxic products as possible.

We must envision the day when machine operators can work in an environment free of dust, pollen and dangerous chemicals. With this need comes the demand for a filtration system that will work satisfactorily with a broad band of materials.

We must also envision the operator working in an environment of controlled temperature and humidity. The surroundings should be equal to those that he would find in his own home or automobile. Actually, many farmers spend more time on their tractors than they do in their automobile. It's time they demand the same comfort.

We must also envision a remote controlled system for extremely hazardous jobs and somewhere in the future this type of machine for most farm operations. Considerable work has been done on this problem, however, much more work needs to be done before this is feasible.

Finally, it is necessary that we be realistic in the development of standards. It is of no benefit to set a standard if it cannot be attained.

1/ National Safety Council, Tractor Fatalities, Characteristics of 789 Cases, 1960-1965. Farm Department, National Safety Council, 425 North Michigan Avenue, Chicago, Illinois 60611.

2/ Schnieder, Rollin D., A Study of the Frequency and Type of Tractor Overturns on Nebraska Highways and Farms. 1966-1968. Studies and Training Division, University of Nebraska, Lincoln, Nebraska 68503.

3/ Stuckey, W. E., An Analysis, Ohio Farm Tractor Fatal Accidents, 1956-1967. Cooperative Extension Service, The Ohio State University, Columbus, Ohio.

4/ Willsey, F. R. and Liljedahl, J. B., A Study of Tractor Overturning Accidents, American Society of Agricultural Engineers, Paper 69-639, December 9-12, 1969, Chicago, Illinois.

5/ Worthington, Wayne H., 50 Years of Agricultural Tractor Development, Society of Automotive Engineers, Paper 660584, Milwaukee, Wisconsin, September 12-15, 1966.

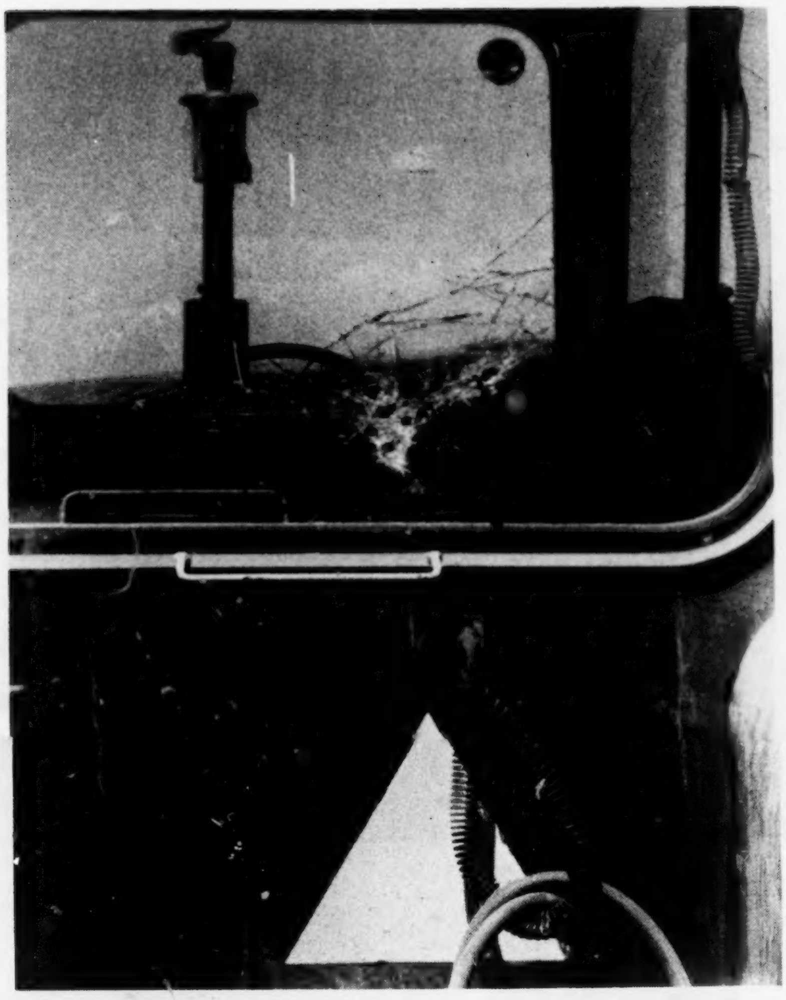


Figure 1. This is an Egging cab which was struck by a flying hook which broke when plowing. The operator was protected by the cab.

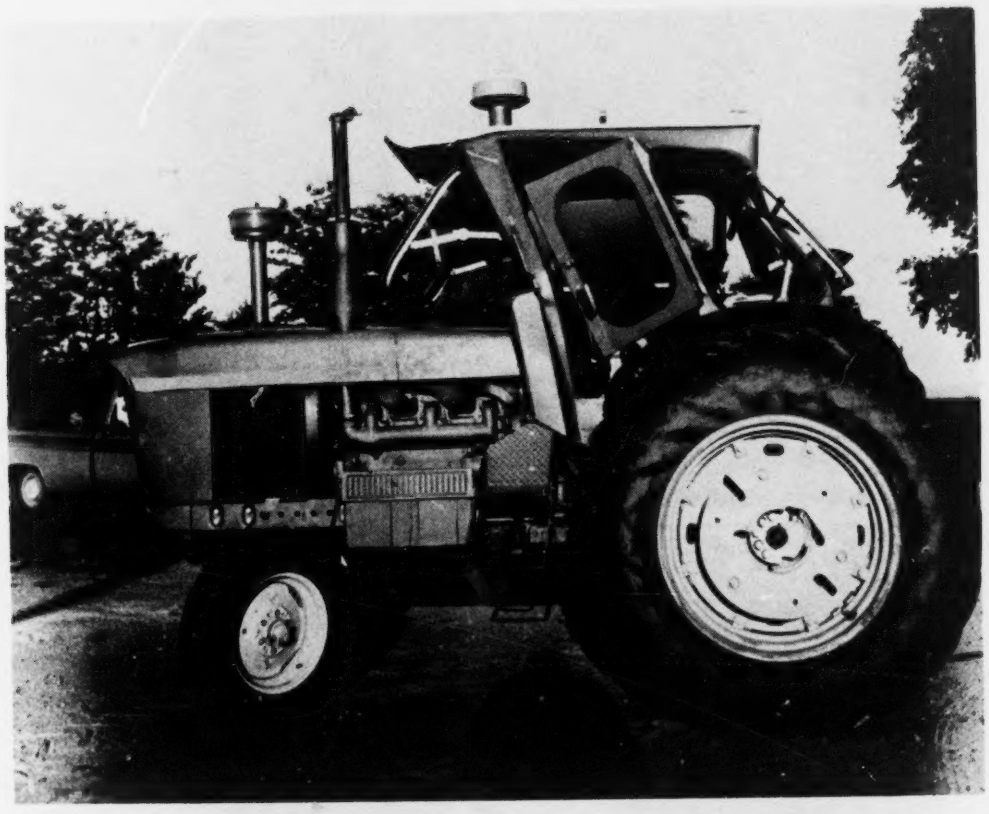


Figure 2. This tractor was involved in a backward overturn. The 16 year old operator emerged with a bruised elbow. Two weeks later the boy was again protected from a serious injury when a chain broke as he was pulling a truck. A new cab on the tractor provided the protection.

CIS

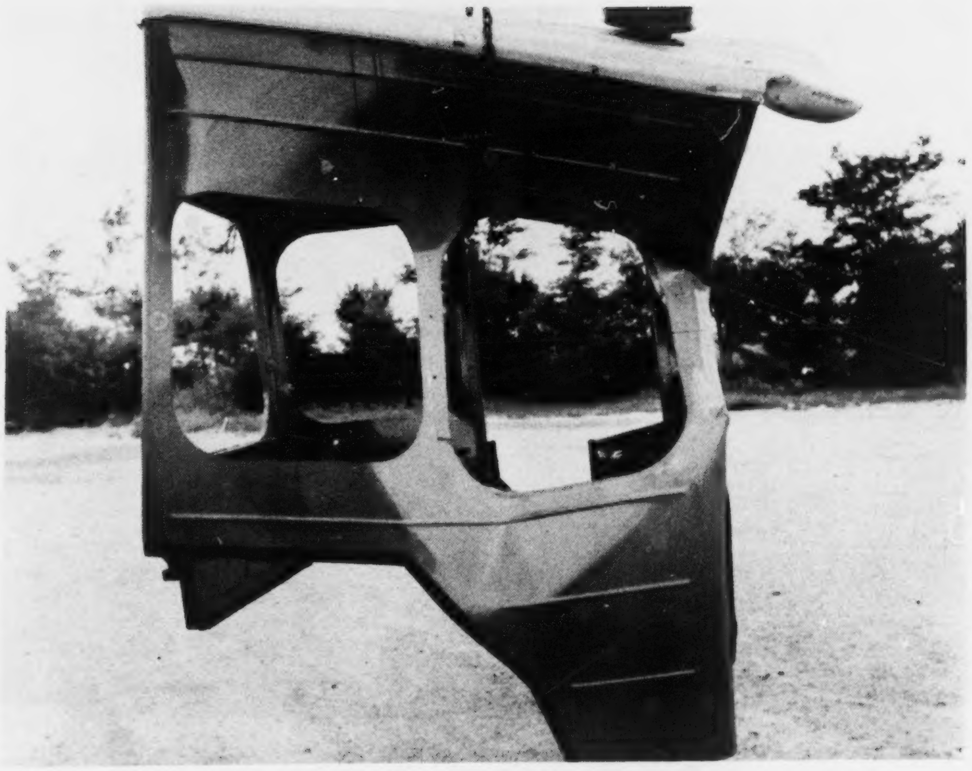


Figure 3. Although this is not a crush resistant cab, it did give protection when the tractor overturned.

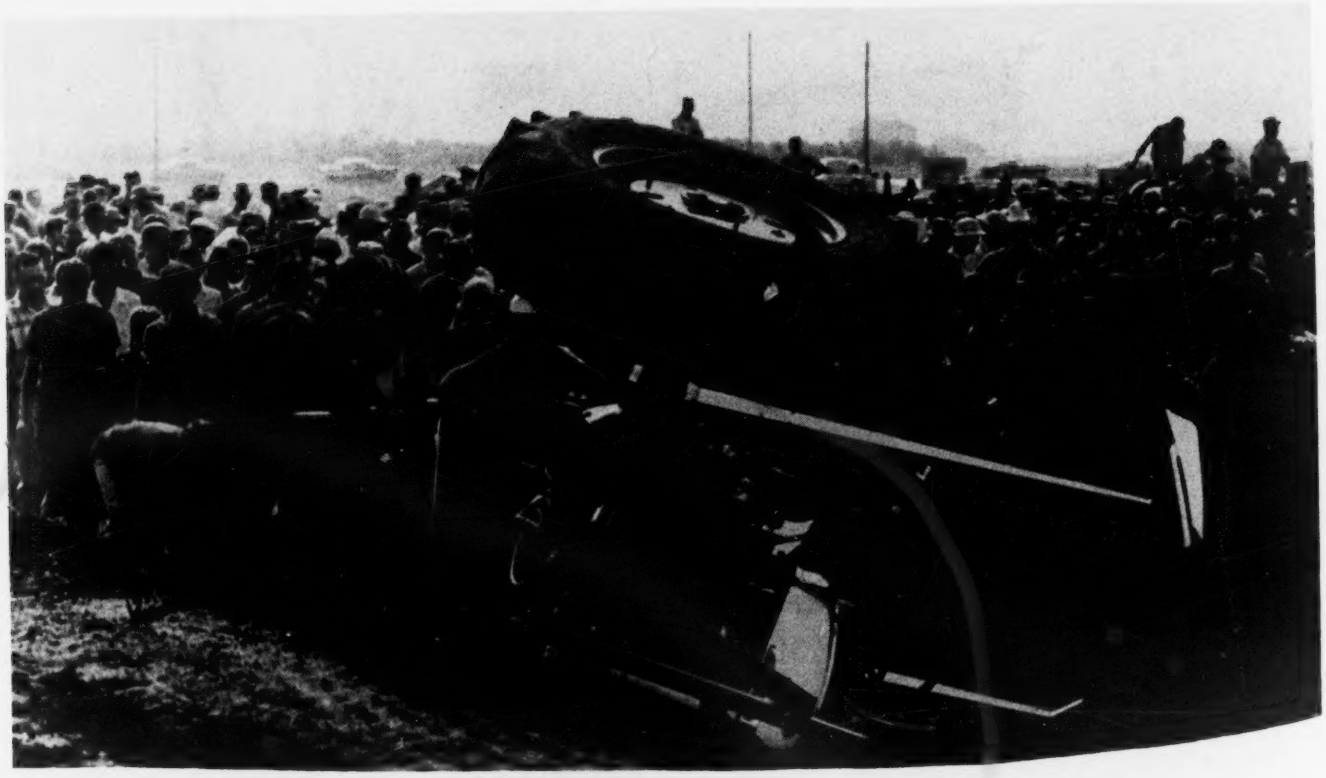


Figure 4. Deere and Company cooperated in putting on this overturn demonstration at the 1966 Nebraska Tractor Power and Safety Day.

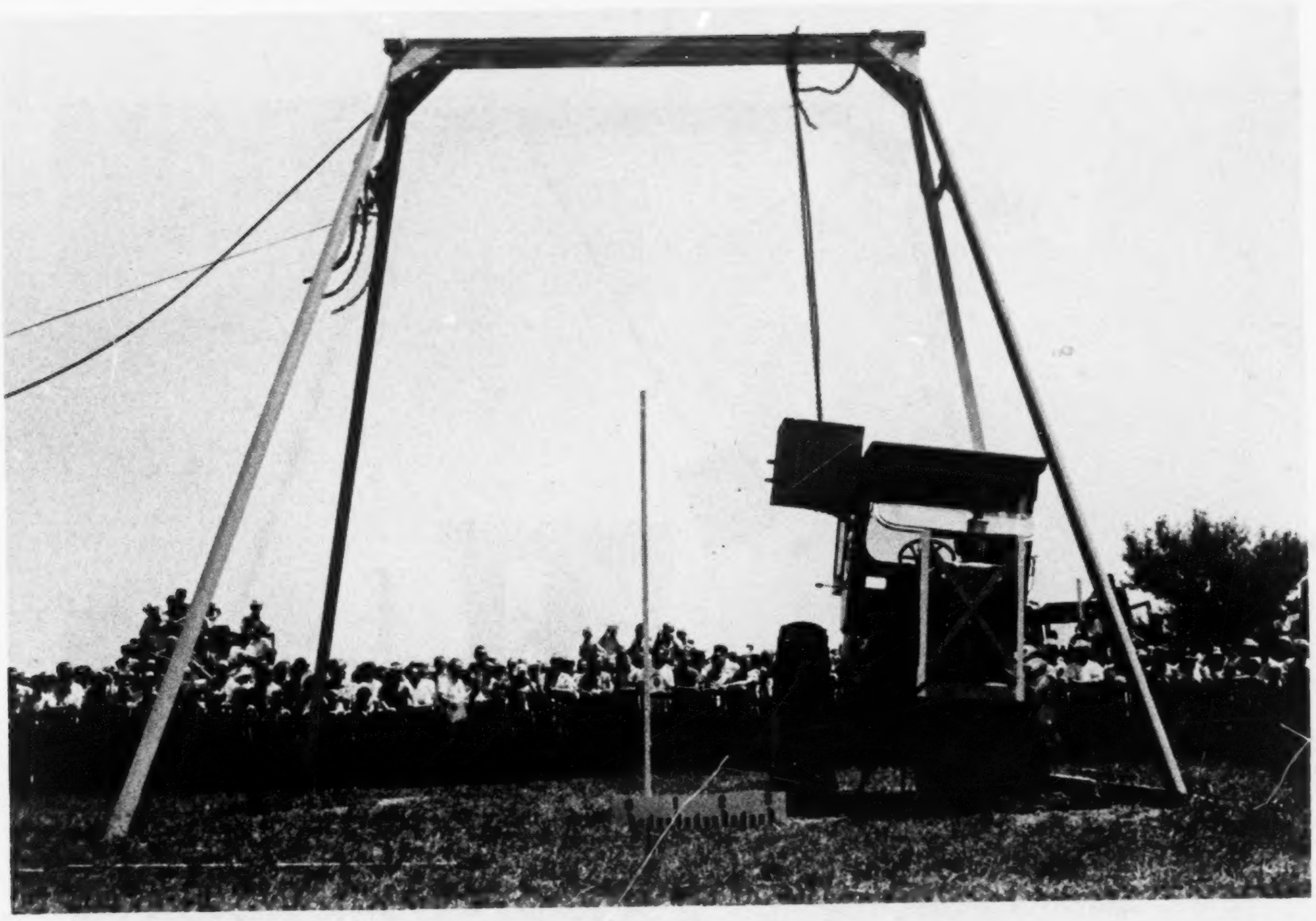


Figure 5. A side impact pendulum test is demonstrated at the 1969 Nebraska Tractor Power and Safety Day.

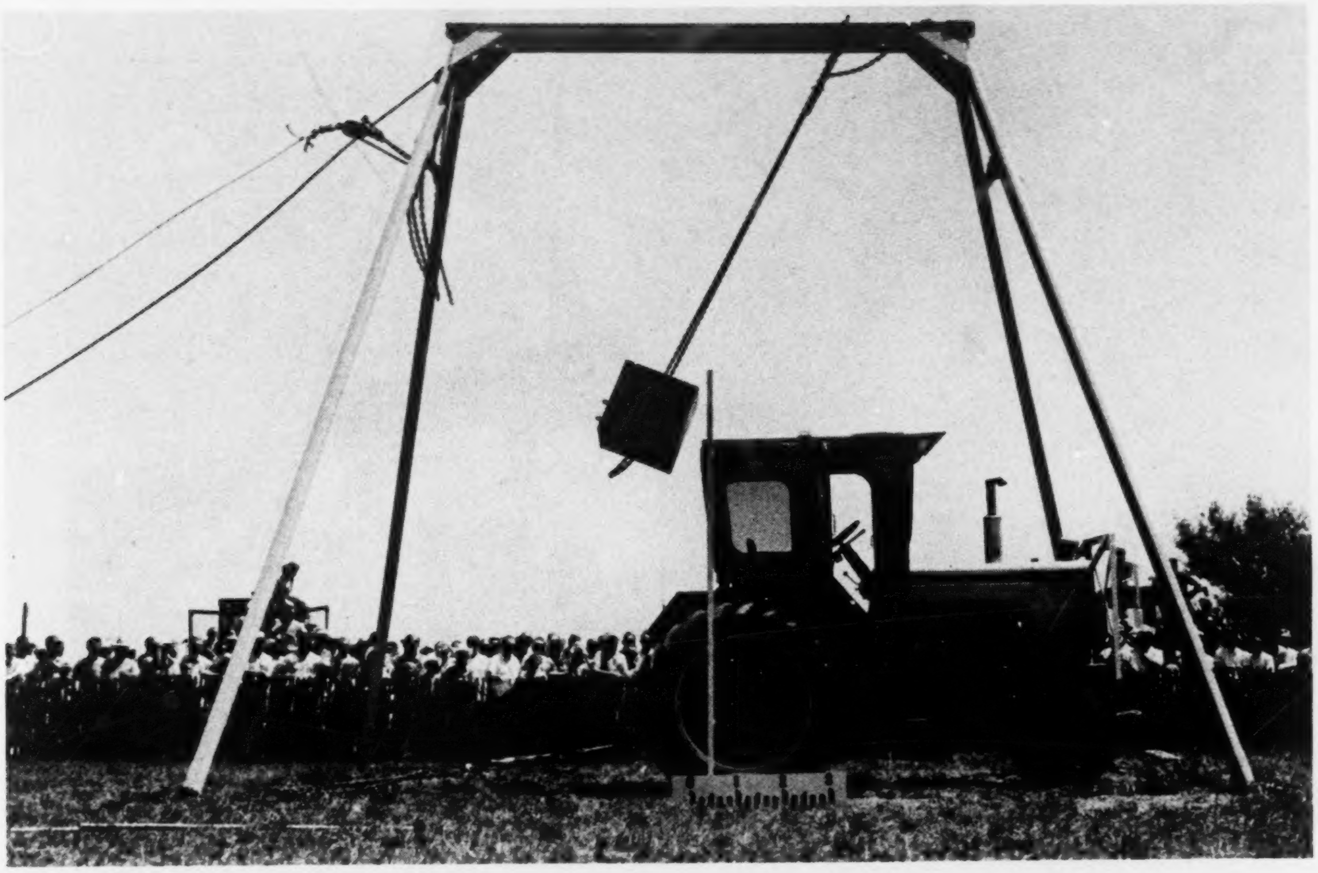


Figure 6. A rear impact pendulum test is demonstrated at the 1969 Nebraska Tractor Power and Safety Day.

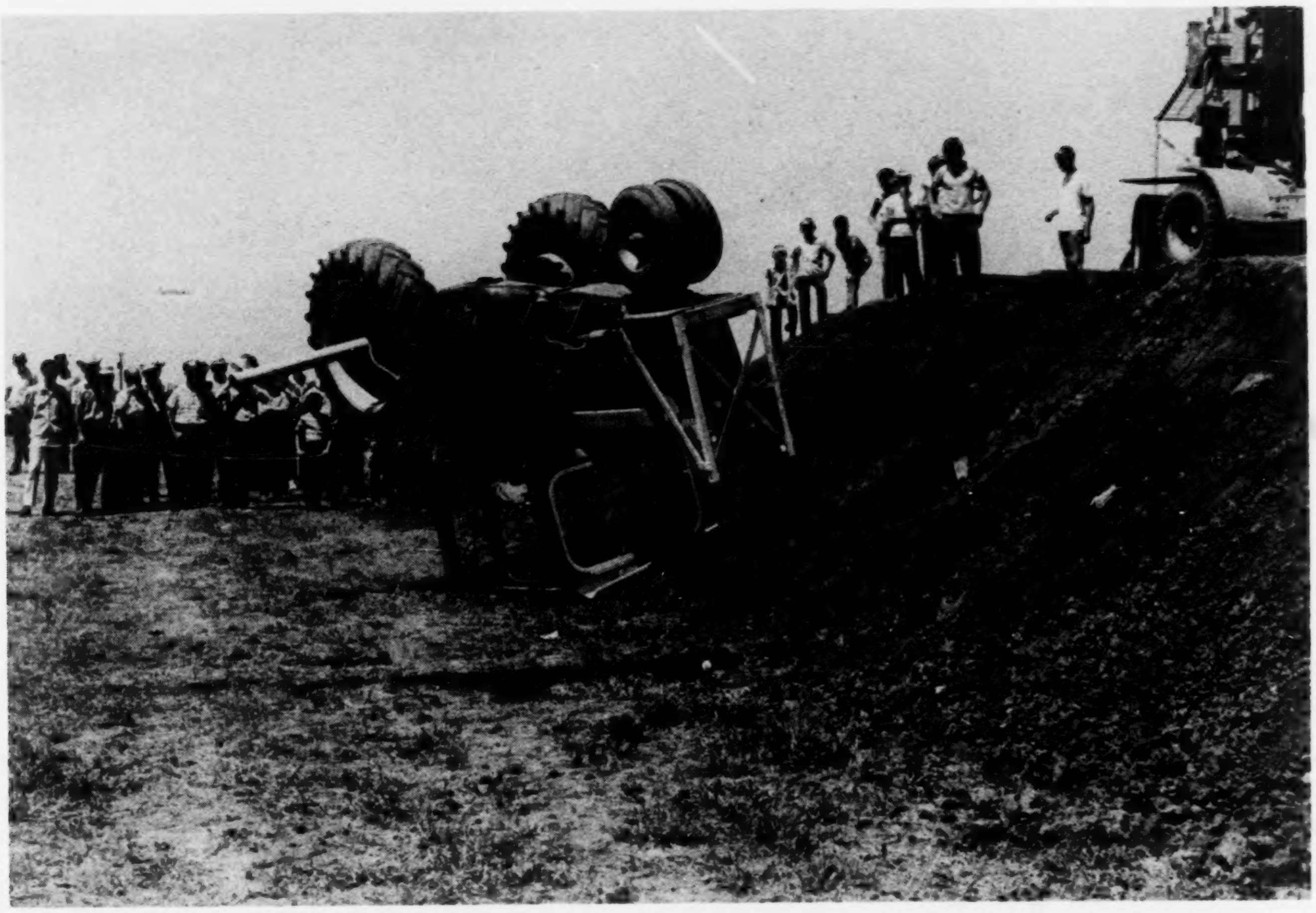


Figure 7. A tractor overturn demonstration at the 1970 Nebraska Tractor Power and Safety Day, shows the benefit of a crush resistant cab.

WATERLOO BOY
KEROSENE
WATERLOO BOY

IN 1920: John Deere's Waterloo Boy was the first tractor to complete the testing under Nebraska's new Test Law. Here is ASAE Life Fellow Chauncey W. Smith, long-time Tractor Test Board member, and that first tractor. Smith headed the NTTB in 1947. NTT data on tractors currently on the market is carried in AGRICULTURAL ENGINEERS YEARBOOK; tractors are tested according to a code approved by ASAE and SAE

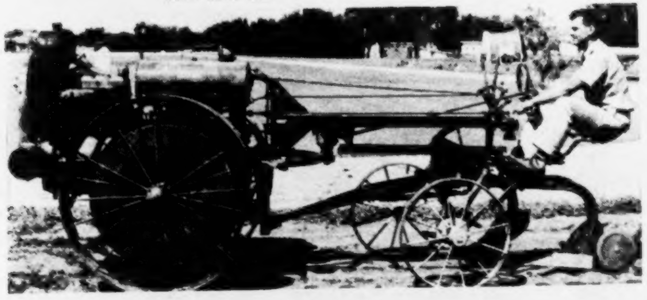
YEAR	HIGHLIGHTS		TEST NO.	MAKE & MODEL
1919	The Nebraska Tractor Test Law passed by the Legislature			
1920	Completion of first official test		1.	Waterloo Boy "N"
1920	Cast iron unit frame construction and water bath air cleaner.		18	Fordson
1920	Early garden-type tractor		28	Beeman "G"
1920	Earliest practical approach to a general purpose tractor — storage battery, starter, lights, electric governor, high-tension battery ignition system, turning brakes, differential lock and high-speed (1800 rpm) engine		33	Moline Universal "D" 9-18
1920	First crawler tractor		45	Cletrac "W" 12-20
1920	One piece boiler plate unit-frame construction		49	Wallis 15-25
1920	Last tractor to retain the outward appearance of a steam traction engine		63	Townsend 15-30
1920	Mechanical lift with direct engine drive		66	Square Turn 18-35
1922	Articulated four wheel drive with hydraulic power steering		84	Rogers Four Wheel Drive
1922	A practical power take-off and one piece cast frame construction		87	International 15-30
1925	Successful all-purpose row crop tractor		117	McCormick-Deering "Farmall"
1926	Distillate fuel replaces kerosene		128	Hart-Parr 18-36
1927	Certified performance		134	Wallis 20-30
1930	Imported tractor (from Ireland)		173	Fordson "F"
1930	"Tip-Toe" wheels with adjustable spacing on splined axles		176	Oliver Hart-Parr ROW CROP
1931	Two speed belt pulley which could also operate in reverse		192	Bradley "General Purpose"
1932	Early diesel tractor (crawler)		208	Caterpillar "Diesel"
1934	Hydraulic lift available		222	John Deere GP "A"
1934	Pneumatic tires on a tractor		223	Allis-Chalmers "WC"
1934	Last test using kerosene		229	McCormick-Deering W-12
1935	Diesel engine in wheel-type tractor		246	McCormick-Deering "WD-40"
1936	High compression engines for tractors		249 252	Minneapolis-Moline Twin City KTA HC Oliver Hart-Parr 70 HC
1937	Hesselman (fuel injection with spark ignition)		285	Allis-Chalmers WK-O Dsl.
1938	Compact or "baby" tractor (rubber tires)		302	Allis-Chalmers B
1940	Three-point hitch and hydraulic draft control		339	Ford-Ferguson System 9N
1940	Two-cycle diesel engine in a crawler		360	Allis-Chalmers HD-7W
1948	Torque converter (crawler)		397	Allis-Chalmers HD-19
1947	Independent PTO		382	Cockshutt 30 Gasoline
1948	Engine mounted behind rear axle		398	Allis-Chalmers G
1948	Power spacing wheels		399	Allis-Chalmers WD Tractor Fuel
1949	Tractor using LPG		411	Minneapolis-Moline Universal Standard
1953	LPG fuel tank mounted in front of radiator		512	Allis-Chalmers WD-45 LP
1954	Hydraulic power assist steering		528	John Deere 70 Diesel
1955	Partial power shift transmission (TA)		532	McCormick Farmall 400
1955	A super-charger used in a crawler		550	Allis-Chalmers HD-21
1955	Turbo-charger used in a crawler		584	Caterpillar D-9
1956	Concrete test course constructed at Nebraska			
1956	Record fuel economy (10 hr run)	8.87 hp-hr/gal 16.56 hp-hr/gal 11.25 hp-hr/gal	590 594 598	John Deere 520 LPG John Deere 720 Diesel John Deere 620 Gas
1956	Last use of distillate fuel during a test		606	John Deere 720 All Fuel
1958	Torque converter with lock-out		679	Case 811-B
1959	Starting PTO testing at Nebraska		681	Fordson Dexta Diesel
1959	Air-cooled diesel engine in a tractor		699	Porsche Diesel Jr. L108
1959	Cab and air conditioner (4-wheel drive)		700	Wagner TR-14A Diesel
1959	Full power shift transmission		701	Ford 881
1959	Radial tractor tire		707	Fiat 411 R Diesel
1960	Hydrostatic power steering		759	John Deere 4010 Gas
1960	Front mounted fuel tank (rubber tired tractor)		759	John Deere 4010 Gas
1962	Turbocharger used in wheel-type tractor		811	Allis-Chalmers D-19
1962	Largest wheel tractor tested (crab steering)		815	International 4300
1963	Alternator charging system		855	Allis-Chalmers D-21
1964	Vacuum advance distributor		874	Oliver 1650
1965	Rear mounted fuel tank (general purpose tractor)		918	Case 930 GP Diesel
1965	Driver's seat raised and lowered hydraulically		923	Massey-Ferguson 1100 Diesel
1965	Saddle mounted fuel tanks		923	Massey-Ferguson 1100 Diesel
1966	Roll guard protection for operator		934	John Deere 4020 S. R. LPG
1967	Hydrostatic drive		967	International 656 Hydro Diesel
1968	Fender tanks for fuel		986	Oliver 2150 Row Crop Diesel
1969	Transistorized ignition system		1007	International 544 Hydro Gas
1969	Cab and roll guard protection for operator		1026	Ford 8000 Diesel
1969	Non-metallic fuel tank		1030	Case 870 P. S. Diesel
1970	Official sound testing		1034	Case 970 Diesel

50 Years of
NEBRASKA TEST HIGHLIGHTS

ON NTT BOARD: Many ASAE'ers have served on the Test Board. At left, Francis D. Yung and Lester F. Larsen, engineer-in-charge at the Nebraska lab. ● Below — ASAE Fellow Carlton Zink, who was in charge of testing from 1930 to 1942, is shown with the late Elmer E. Brackett and the late Lloyd W. Hurlbut, both ASAE past-presidents. Here are a few pictorial highlights in the Nebraska Test program. Numbers on the photographs correspond with test numbers on the opposite page.

These photos and details on the NTT program were supplied by ASAE Member Larsen

Test No. 33



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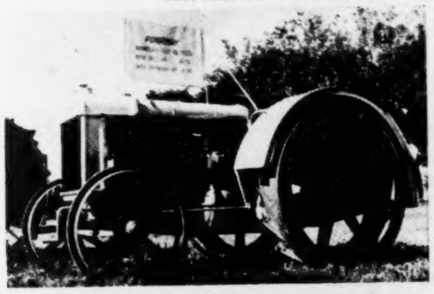

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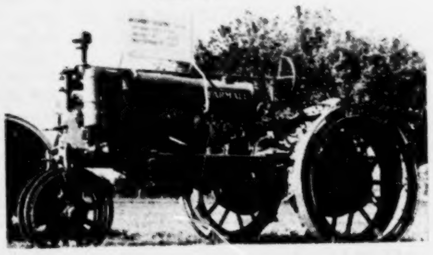

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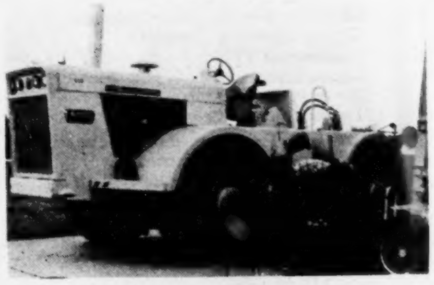

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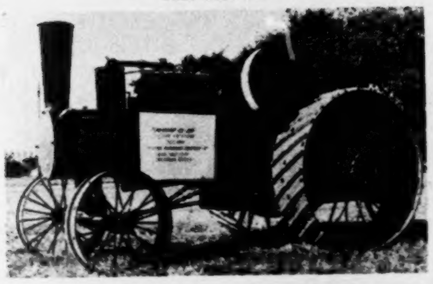

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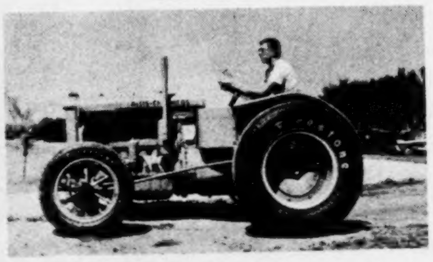

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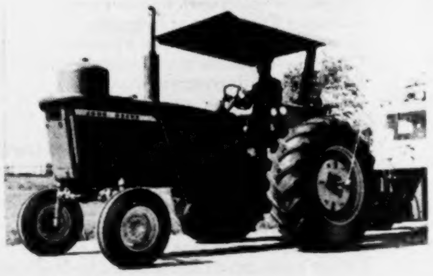
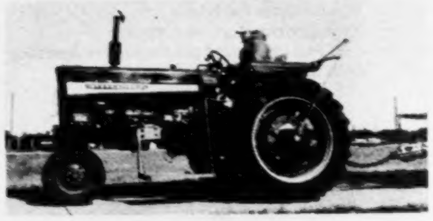


Test No. 66

Test No. 339

Test No. 967



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of Nebraska Quarterly

Many N.U. Services For Farmers

Ralston J. Graham

The University of Nebraska Tractor Testing Laboratory has been encouraging manufacturers to improve tractor performance since 1919. Known to farmers and dealers throughout Nebraska and all other states, and to manufacturers the world over, the Laboratory probably has brought the University as much fame as the Cornhusker football team. *Popular Science* magazine has referred to the Laboratory as "the supreme court of tractors."

One of the oldest and most productive tractor testing facilities in the world, the Laboratory completed its 1,000th official test in 1968. Since then the total has risen to 1,048.

The Nebraska Laboratory was established under provisions of a law passed by the Nebraska Legislature which went into effect in 1919. W. F. Crozier introduced the bill, which established compulsory testing of all tractors sold in Nebraska for agricultural purposes.

World Standard

Although several countries in Europe and Australia have developed tractor test facilities, the Nebraska Laboratory is the only such facility in the western hemisphere, and is regarded as the world standard.

Manufacturers in Japan, Poland, Czechoslovakia, France, Ireland, Canada, Italy, England, Sweden, and Germany as well as all United States companies producing tractors have requested and received performance tests at the Nebraska Laboratory.

Purposes of the test law are to regulate manufacturers' claims, encourage tractor improvement, assure a stock of repairs for each model in the state, give impartial test results, make test results available to the public, show each tractor's comparative performance on all fuels, and test tractor transmissions.

Manufacturers pay a fee for each model tested. Thus the Laboratory is self-supporting, and does not depend on tax funds for its operation. Each tractor is tested for its performance on the drawbar and the power take-off. Testing of belt horsepower has almost been discontinued.

The Nebraska Tractor Testing Board, composed exclusively of engineers, is now developing tests to evaluate a tractor's upset resistance, its noisiness and the degree to which its waste causes air pollution. The objective of these new tests will concern the health, safety and comfort of the driver, as well as the mechanical performance of the tractor.

The smallest tractor tested over the years was the one-horsepower Choremaster and the largest wheel-type tractor tested was the International 4300. One crawler tractor devleoped more than 250 horsepower. The average horsepower of the 65 tractors tested in 1920 was 33.5. In 1969, the average horsepower of tractors tested was 78, according to Professor L. F. Larsen, engineer in charge of the Laboratory.

Other Services

Within Nebraska, two other services offered by the College of Agriculture are as well known and useful to farmers as tractor testing. They are the Soil Testing Laboratory and the Veterinary Diagnostic Laboratory.

Each year an average of 4,000 farmers sent soil samples to the College for checks on the status of nitrogen, phosphorus, potassium and minor nutrients in their soil, and on the need for lime. Another 7,000 samples come to the Laboratory from University research plots established over the state by the University's Agricultural Experiment Station.

Farmers send their samples to the Laboratory through their county Extension agents or fertilizer dealers with a fee which varies with the type of test requested. In addition to any specific information requested, each farmer sending a sample receives a general nitrogen recommendation based on the sample and on the cropping history information that accompanies it.

In charge of testing and responsible for recommendations is Delno Knudsen, who has been in charge since 1953, except for a short time recently when he took leave to study for his Ph.D. degree.

Irrigation Water

Also available through the Laboratory are analyses of irrigation water. The analyses include tests for plant nutrient value of the water and for water quality as it is affected by carbonates, bicarbonates, pH, calcium, magnesium, sodium, and soluble salts.

"Farmers need to know what nutrients their irrigation water contains so they may apply fertilizer accordingly," Knudsen contends. "Some farmers have soluble salts or sodium in their water and may need to over-irrigate to flush out certain minerals when they accumulate in the soil. Good quality irrigation water can also be used to reclaim soils that contain large amounts of sodium and/or soluble salts. The water quality analysis will also indicate the presence of nitrates, which is becoming a big problem in relation to water pollution in some areas of the country."

Farmers who had water samples analyzed in 1961 or 1962 are especially encouraged to have a recheck made now, according to Knudsen, because very little information is available on the chemical change that takes place in ground water after years of extensive irrigation.

(continued on next page)

Veterinary Lab

The Veterinary Diagnostic Laboratory serves Nebraska's huge livestock industry in the diagnosis of disease in cattle, swine, sheep, poultry and horses. It is an important key in disease control and eradication programs such as hog cholera, brucellosis and tuberculosis.

The Laboratory service is provided to animal owners directly or through their practicing veterinarians. As a corollary benefit, the Laboratory offers training for graduate students in agriculture and Veterinary Science, and its staff cooperates in disease research problems with other departments.

The first full time researcher in agriculture to investigate livestock disease problems was Dr. Frank S. Billings in 1886. The diseases of great concern at that time were Texas cattle fever, cornstalk disease and, then as now, hog cholera.

Today the Diagnostic Laboratory conducts serological, bacteriological, virological, histological, chemical, and hematological examinations on specimens and tissues from animal origin.

During 1969 the Laboratory received 1,740 accessions, according to Dr. Marvin J. Twiehaus, Chairman of the Department of Veterinary Science. Many of these accessions contained more than one specimen.

The specimens are submitted from every part of the state and also from bordering states. With the opening in April 1969 of a new Diagnostic Laboratory at the University's North Platte Station, most specimens from central and western Nebraska are now being directed to that facility.

The new Laboratory had 868 accessions in 1969. The number up to mid-June 1970 was 1,350 and Dr. Clair M. Hibbs estimated that this would reach 2,000 by the end of the year. The North Platte staff counts each specimen as an acquisition.

Ralston J. Graham is Extension Editor and Chairman of the Department of Information.

AGRICULTURAL TRACTOR DESIGN

and

SAFE OPERATION

Prepared by: Dr. Norval J. Wardle
for the U. S. Department of
Transportation

21 September 1970

BACKGROUND

The number of people supplied food by each farmer has quadrupled in just 30 years in America. Each farmer now produces food for over 40 other people.

Just since 1950, labor efficiency on American farms has increased by 6½ percent each year. Productivity has increased more rapidly in agriculture than in any industry. This has been a result of improved seed, controlled irrigation, selective methods of harvesting, artificial drying of crops, improved disease and insect control, sophistication of mechanization. Agricultural machinery is the imput factor which has been most readily varied by the farmer to improve his overall efficiency.

POWER INCREASE

The pressure to produce more efficiently at a lower cost has resulted in a doubling of the horsepower at work on American farms in the last 20 years. This does not mean there are twice as many machines. It is mostly a result of more powerful machines which reduce the man imput in relation to total work done. On American farms, we now have over 200 million horsepower in tractors, with 4½ million farm workers, doing over 7 billion labor hours. The pressure increases for larger and more complicated tractors, for larger and more complicated mechanization systems operated by one man. The pressure for more and more power is on the farmer, the farm machinery dealer, the farm machinery manufacturer.

Change, complicated change, is coming so rapidly in mechanized agriculture. We have sophisticated functional operating machines which are not sophisticated in relation to the man who must operate them. This is a critical problem. It is costing the lives of 1,500 valuable American farm workers each year. Tractor accidents alone account for over 1,000 deaths; 30,000 doctor-treated and over 200,000 lost time accidents in America each year. This must not continue.

The modern farm is a complex business, however, the family of the farm owner, manager and worker, is still closely associated with the farm operations in many ways. They usually live within the physical confines of the operations. There is no barrier set up to keep the children and wife from coming to where the farm worker is operating complex machinery. The machinery looks interesting. Especially children are attracted to a closer look, a desire to "ride with Daddy." This facet of farm life must be considered in tractor and machinery design, construction and operation. We can not continue slaughtering and maiming little children and using the defense, "They shouldn't be there." "Keep the children away." We must make tractors and machinery as child safe as possible.

A BRIEF HISTORY OF TRACTOR DEVELOPMENTS

The number of companies who manufactured farm tractors has varied. There were one or two in 1895, a peak of 186 in 1918 and around 50 in 1950. Over 500 companies have manufactured tractors in the United States. "During the 17th century, as a result of widespread interest in scientific research in Europe, experiments on heat engines were taking place in many countries. While the origin of the internal combustion engine is obscure, the present engine is the result of long-continued development the early stages of which were mainly exploratory in character. For instance, Huyghens, a dutch physicist in 1680 experimented with gun powder. Thomas Newcomen in 1705 made a practical success of an atmospheric engine. Indeed, more than twenty-one centuries ago, Hero of Alexandria (130 B.C.) described an apparatus that made use of heated air for opening and closing temple doors. This is the first air engine of record and the first device known to do mechanical work with expanded air." [1]

"The 'steam plow', or traction engine, was the forerunner of the gasoline tractor and the first step of importance in mechanical power farming in this and other countries. In addition to the demand for steam power for plowing, new farm machines invented in the first half of the 19th century stimulated a need for mechanical power. In 1831 McCormick invented his reaper. This was soon to create a demand for belt power with which to thresh the mechanically harvested grain crops. By 1847 the Pitts pattern threshing machine was being built by many shops from Main to Mississippi and by 1860 over 50 shops were building threshers under license from Pitts Brothers. Shortly thereafter, steel plows, mowers, shellers, fodder cutters, and other machines were being offered to the farmer. With the invention of the reaper and the development of threshers, the flail with its limited threshing capacity, became obsolete."[1]

"Farmers started buying self-propelled steam engines in the later 1870's in considerable numbers. In 1890 approximately 300 steam tractors and 2,661 steam threshers were built. In 1894 several plow manufacturers advertised multiple-bottom steam tractor plows or gangs. By 1900 more than 30 firms were manufacturing some 5,000 large steam-traction engines a year. These tractors were greatly improved over earlier models. The gearing, shafting, and other wearing parts were built to withstand the immense strains imposed upon them in pulling large threshers, and plowing many furrows at one time. About this time the Geiser and Friede Companies both of Waynesboro, Pennsylvania offered to the trade, steam-lifts for engine gangs. This development indicated, even this early, that thought was being given to cutting down labor requirements in plowing; also to lightening the burden of manually lifting the plows by levers which were continually sticking or giving trouble and resulting in the use of very strong language by the operator."[1]

"In 1794 Robert Street, also an Englishman, "patented the first real engine. It contained a cylinder in which worked a piston connected to a lever and operated a pump. Turpentine as the fuel, was introduced and heated, and the air drawn in produced the combustible mixture."[1]

"An explosion-type engine was patented in 1801 by Lebon D'Humbersin, a Frenchman, who is classed by some as the father of the present day internal combustion engine. In his gas motor, both the gas and the air were compressed in external chambers previous to ignition."[1]

"Beau de Rochas, a French engineer, about this time (1860) formulated the theory of the cycle of operations to utilize more efficently the heat supplied. He laid down conditions from which resulted the four-cycle principle embodying compressing of the charge before ignition."[1]

The internal combustion engine as a practical power unit began to assume importance with the Otto Engine in 1876. This was not Otto's first effort, however, for 1861 he attempted to improve on Lenoir's engine by giving it a full power stroke, and later with Langen, Otto invented an entirely new type known as the free-piston engine."[1]

In development, the tractor followed the pattern of the steam traction engine. The engine was mounted on skids so it could be moved by horses to where it would be used. Then a drive of some kind was developed for self-propulsion. Tractors were the answer to man's desire to increase his productive control. A man continuously can produce directly about 0.1 horsepower. As a power unit a man is worth less than 1 cent per hour. As an operator of a 20 horsepower tractor he controls the equivalent of 200 men, with a 100 horsepower tractor, 1,000 men.

The early tractors were built on steam engine frames to get farmers to accept them and because it is always easier to use something which is already present and try to adapt it. This latter is the cause of many design problems. The first Winnepeg tractor trials were in 1908, the first in the United States were at Omaha in 1911. These allowed the farmers to see both steam and gas tractors in comparable field operations.

From 1910 - 1920 many companies went into tractor production by purchasing most of the parts from automobile sources and assembling them into tractors. The failure of this kind of production demonstrated the critical difference between requirements of automobiles and of tractors.

"In 1895 the Waterloo Gasoline Traction Engine Co. (organized in 1893) was reorganized as the Waterloo Gasoline Engine Co. Having achieved considerable success in building gasoline engines, this concern continued its program of building experimental tractors. Almost 20 years passed, however, before this company began production of its kerosene-burning tractor known as the "Waterloo Boy."[1]

"Early in 1906 the International Harvester Co. built 200 single cylinder tractors with friction drive. Later in the year the design was changed to include a sliding gear transmission system with two forward speeds and one reverse, a friction clutch, and a final drive gear. In 1907 The Ford Motor Co. of Detroit, Michigan produced an experimental tractor using some of the parts from a Ford car and a binder. Also in 1907 Hart-Parr produced their Model '60' and in 1908 their 40 - 80 horsepower model. While this latter model weighed 34,000 pounds the use of the so-called tricycle arrangement of wheels was made use of. This tractor appears to have been in little demand.

"The origin of the word 'tractor' is credited to the year 1906 and popular establishment of the name 'tractor' to replace the longer expression ' gasoline traction engine' is commonly attributed to Charles W. Hart and Charles H. Parr of Charles City, Iowa, who are credited with having built the first successful internal combustion engine tractor and founding the gasoline tractor industry; or to W. H. Williams, Sales Manager of the company who 'sat puzzling over an advertisement he was writing. The words "gasoline traction engine' were too cumbersome. In his mind came visions of a new word - 'tractor'. He acted on the impulse and wrote the word into the ad." However, it developed that the word had been coined by 1890 when it first appeared on record in patent No. 425,600 issued on a tractor invented by George H. Edwards of Chicago.

"In 1906 the first tractor school in the U.S. was held at the Minnesota State Fair grounds in St. Paul, under the direction of D. D. Mayne, Principal, School of Agriculture, University of Minnesota, and B. B. Clarke, Editor, American Thresherman. Chief instructors were William Boss of the University of Minnesota and Philip S. Rose of the North Dakota Agricultural College. H. B. White, also of the University of Minnesota, was in charge of practice work. This was the beginning of the school work which has since been carried on in practically all agricultural colleges and by tractor manufacturers."[1]

It is well to note in relation to the schools just mentioned that for many years these schools have been primarily demonstrations of new equipment with little actual training of farm operators in actual operation of the equipment. This needs to be revived as in the beginning.

"With few exceptions, the gasoline tractor engines manufactured through 1910 were of the four-stroke cycle (four cycle), had automatic intake valves, hit-and-miss governors for controlling their speed, and make-and-break ignition systems. As a rule, electric current for ignition was supplied by dry batteries for starting, and a low voltage DC magneto or generator (auto sparker) furnished the current thereafter. In some cases a low-voltage oscillating magneto furnished the spark required for starting and running. The frames of the tractors were built up of channel irons to which engine and other parts were bolted. Most large transmission gears were of cast iron, exposed to the weather, and the drive wheels often turned on a one-piece 'dead' or floating axle. Selective type of transmission was most commonly used, although friction drive and planetary gear transmissions were not uncommon, and a wide variety of clutches was provided."[1]

In 1912 the Backer Tractor, Royal Oaks, Michigan, manufactured a tractor controlled and guided by reins. It operated by electric motors mounted on the axle within each drive wheel. Eleccurrent was from a generator driven by the tractor engine.

"The Ford Motor Co. of Detroit, producted (1917) for the trade its first tractor -- the Fordson. This was the first tractor to make use of cast iron unit frame construction and it was not long until practically all of the tractor manufacturers adopted this type of design. The previous model was constructed with the worm drive overhead but because of lubricating difficulties the worm was placed underneath. The heating caused by the overhead worm would cause the housing to become so hot that the driver's seat became unbearable.

"The demand for tractors was so great because of wartime agricultural needs that several companies made adaptations for the Ford and other cars so they could serve as tractors. An example of this activity was the Feeney Tractor Addition built for a Ford chassis by the Farmers Tractor Co. of Chicago."[1]

"An important development of the year (1918) was the introduction by the International Harvester of a practicable power take-off mechanism on its tractors. This permitted operating and controlling mounted and drawn equipment by the tractors own engine, through a special shaft and under control of the operator. It was not many years until all of the leading manufacturers had their tractors so equipped.

"The majority of tractors which appeared up to 1916 or 1917 were designed mainly for drawbar work and possibly to a lesser extent for belt pulley. They were heavy and not adapted to cultivation. The need for tractors which would perform this operation, especially in corn, was rapidly becoming apparent and the so-called motor-cultivator began to appear. After a few years of development the first Corn Belt Cultivator demonstration was staged at Blue Mound, Ill., in 1919. Participants included Avery, Emrson-Brantingham, Illinois, Moline Plow Co., Toro Motor Co., Allis-Chambers, and International Harvester Co."[1]

TRACTOR TESTING

In 1919 Ohio State University tested tractors pulling plows in several sections of the State. The results were published. The report included identification of the tractor, weight, plowing speed, pounds of pull, rate of travel, depth plowed and horsepower.

In the same year the State of Nebraska passed "a bill to provide official tests for gas, gasoline, kerosene, distillate, or other liquid fuel traction engines in the State of Nebraska and to compel the maintenance of adequate service stations for same." The tests are still in operation. The reports of the Nebraska Tractor Tests are published including description of tractor, PTO performance and drawbar performance.

The Ohio Tests and the Nebraska Tests through the years have been concerned with power production of the tractor. Under the drawbar test of the later, it states, "safe stability limits of the tractor must not be exceeded." There is no explanation, no guidelines, no parameters, no instruction to make the judgment uniform nor effective. It is as though it were thought that the term, "Safe stability limits of the tractor" were something understood by all. Rather, it is likely put that way, because they did not know what the guidelines were and covered up with a high sounding, inclusive phrase. It just simply left such a decision to the full judgment of each person conducting the tests.

In 1969 the Nebraska Tests did start some work on noise level measurement. Previous to the enactment of the Nebraska law, there had been some agitation for a National Testing Station. Such was never developed. All the discussion and promotion of tractor testing was for functional performance testing. That is very good and necessary. However, there was never any suggestion or consideration in fact of testing the tractor for safety.

ACCESSORIES AND COMPONENT PARTS

"The early tractors were used principally for plowing the buffalo range prairies extending from Oklahoma to Edmonton, Canada, which were being converted to growing wheat. Although some use was being made of them, in season, for driving threshers, it was not until about the middle of the 1909 1920 period that their use for the purpose became general. Belt pulleys were available ordinarily only as special features on most models, and it was several years before the pulley became standard equipment.

"The steam tractor was kept for threshing work long after it ceased to be a factor in plowing but was gradually replaced by gas tractors. With the prairies largely broken up demand for large tractors fell off and with the outbreak of the First World War in August 1914 labor to operate them began to get scarce. The next few years saw small one-man tractors in demand.

"While there were many structural defects in engines and power transmission parts, early engine failures were, in a large measure, due to lack of know-how, and poor oil offered to the trade, plus poor lubrication systems."[1]

"In 1918 the United States Department of Agriculture sent questionnaires to over 2,000 tractor operators requesting a report on that part of the tractor which gave the most trouble. Over 900 replies were classified as follows: magneto 299, spark plugs 110, gears 108, carburetors 104, bearings 80, cylinder and pistons 61, clutch 59, valves and springs 43, lubrication 29, starting 28. These figures indicate that the major troubles were with the ignition system, the combined ignition troubles constituting nearly half of the total classified troubles."[1]

Yes, the whole industry, and the farmers, were fully absorbed in functional performance. Until these problems were satisfactorily solved the man-machine relationship would be ignored. After all,

> "It is the careless operator who gets hurt."
> "Anyone could see that whirling power shaft. Only a fool would get caught in it."
> "A careful man won't get caught by a belt."
> "Who ever heard of a guard on a belt? It wouldn't work."
> "A farmer expects a few bruises, cuts, scratches. They are part of the farmer's life."
> "Accidents are caused by careless operators."

All these ideas justified working on functional problems in the design of tractors to the almost complete exclusion of the safety of the operator, a man, a careless farmer. Yet, in the late teens some attempts were made to develop self-steering mechanisms. These were feeble attempts and nothing came of them.

In 1924 the Farmall (International Harvester) "...probably the first successful attempt at building a genuine all-purpose tractor of the tricycle design was placed on the market. ...Up to this time the conventional 4-wheel tractor was the generally accepted type for farm work notwithstanding the fact that it failed to meet the problems of rowcrop cultivation. The new Farmall tractor had high rear-axle clearance, gear drive, automatic braking of either wheel for quick and short turns, small closely spaced front wheels designed to run between crop rows, vertical steering column with steering rod over the top of the tractor, vertical steering wheel, 3 forward and 1 reverse speeds, means of mounting cultivator and other attachments, power take-off working off the transmission and delivering power at the center rear, and belt pulley."[2]

These were functionally good and important improvements, but the increased instability and quick, short turns of this and other row crop tractors, which are still not safely controlled, were to result in tens of thousands of accidents and deaths of farmers.

Power take-off standards prepared by a committee of the American Society of Agricultural Engineers and approved by representative engineers of the leading tractor manufacturers were adopted. This was an important step toward clarifying a much confused development caused by lack of standardization. The power take-off standards specified the type of fitting and size, speed (535 rpm ±10) and direction of shaft rotation. The recommended practice covered such features as vertical distance of end of power take-off shaft from ground, horizontal position of end of shaft, guards, etc. Up to this time the shafts were of different sizes, ran at different speeds and rotated in clockwise or anticlockwise direction. In many cases it was a big job to hitch to a power driven machine. This trend of general purpose, row-crop tractors continued for 20 years.

In the 30's the first development of power lifts for lifting and lowering equipment came into production. Also in the late 30's starting and lighting became standard equipment on most models. Road speeds, which in the early thirties went up to over 30 mph, were reduced in many models to 15 mph.

WORLD WAR II DEVELOPMENTS

"In World War II period, beginning late in 1941, because of the acute manpower shortage, experimental work on tractors was curtailed and few new models appeared. In many instances where possible, substitute materials were used. For example, steel back bearings replaced solid bronze, steel replaced copper where possible and the composition of steel and iron alloys was altered - molybdenum replaced chromium. To offset this, in part, emphasis was being placed on preventative maintenance and repairs of agricultural equipment to prolong its usefullness."[2]

During this time and after the war with the tremendous demand many tractors sold in America had some inferior and poor materials and manufacture.

At the turn of the century a wide variety of the then called gasoline traction engines were in the making. They were crude affairs, barked loudly, frightened horses, were difficult to start and were heavy and inefficient. Their acceptance was slow, the steam boys ridiculed the gasoline boys' efforts and many clashes occurred. Gradually and finally the gas engines won out, and 50 years later, the steam engine became as much of a curiosity as the gasoline traction engine was in 1900, the so-called "iron horse" of that period."[2]

THE RESULT

Through the years there had been tremendous advancement in the efficiency of the farm tractor. The tractor and machinery had changed farming from a man-killing drudgery to a work of skill with drudgery and hard physical work practically removed. This has been a tremendous contribution to American life.

However, in the never-ending rush and drive to make a tractor which will do more and more work, the man, whose drudgery it was to supplant, was almost forgotten and as a result tens of thousands have been killed and countless others injured. Yes, there have been many developments which have contributed to the operator's safety. Here are a few:

1. Reduced his heavy, back-breaking toil by doing the work for him.

2. Developed power lifts to both lift and lower the machines he was pulling or otherwise operating with the tractor.

3. Developed pneumatic, hydraulic remote power to control the functioning of machines while he sits on the tractor seat.

4. Developed ballast anc wheel weights which properly handled can increase stability.

5. Enclosed and encased drive gears, chains, etc. of the tractor itself.

6. Designed the hitch to prevent back tip on the level.

7. Designed a seat which was for more comfortable than the old so-called spring seat.

However, these were developed primarily for increased efficiency. Any safety of the operator resulting was largely incidental. It has been claimed by some that safety first is their motto in tractor design. However, in practice the guiding principles in tractor design have been:

1. Power
2. Maneuverability
3. Crop clearance
4. Economical operation
5. Operator comfort

and when it is considered:

6. Operator safety.

DEVELOPMENT OF SAFETY WITH TRACTORS

Tractors were to provide power, to move loads, to pull land-powered field machinery. That was the purpose. Nothing else mattered at least nothing else was considered in its early design. It was that simple.

However, now the tractor provides:

1. Remote power through PTO, belt and hydraulic drive and the remote electric power.
2. Hydraulic and electric remote control.
3. An implement carrier with front, under, and/or rear mounting.
4. A load mover in forward or reverse at variable speed, width and power.

Along the way of this development minimal thought and attention was given to the operator, to machine-man relationships. Safety with tractors is determined by interaction of man, machine and environment. It is probably impossible to build a machine which is absolutely safe, so that no matter what anyone does with it or around it, he would not be injured.

A tractor is like a pocket-knife, to make a pocket-knife absolutely safe, so you could never cut yourself with it, you would have to remove the blades. Then it would no longer be a pocket knife. So it is with a tractor. The tractor will always have the capability to injure when wrongly used. Nevertheless this should never decimate the continuing, diligent endeavor of designers and manufacturers to design and to manufacture tractors just as safe as possible in every way for the operator and those who may come in contact with them. The guiding principles of tractor design should be:

1. Power with safety and comfort.

2. Maneuverability with safety and comfort.

3. Crop clearance with safety and comfort.

4. Economical operation with safety and comfort.

From the first use of tractors there were accidents. No records were kept. It was part of the game. People would be careless and accidents were bound to occur. A few people thought something could be done to reduce them. He who saw the tragic, maimed victims who had been caught on the patched-up power take-off shafts, or even saw an associate wrapped around a shaft (one of mine was), or even had his own clothes ripped off by such a shaft knew something had to be done.

FEI SAFETY COMMITTEE

In 1934 the farm equipment manufacturers organized a safety committee in the Farm Equipment Institute. Their first task was shielding of power take-off shafts (PTO). Some companies had so-called guards, but they were ineffective. Expecially was this true when a PTO operated machine made by one company was used with a tractor of another manufacturer. During 1935-36 the FEI Safety Committee Advisory Engineering Committee developed a standard PTO including:

1. Fore and aft dimensions.
2. Lateral and vertical dimensions.
3. Shaft sizes.
4. Spline dimensions.
5. Master shield bracket.
6. Power line shield.

This standard was submitted to the American Society of Agricultural Engineers and was adopted as a Standard of that organization in 1937. The standard has been revised over the years. In the 1970 Yearbook of the American Society of Agricultural Engineers there are eight standards on the PTO.

S203.7 540-RPM Power Take-off for Agricultural Tractors.

S204.6 1000-RPM Power Take-off for Agricultural Tractors

S205.1	Agricultural Tractor Power Take-off Definitions and Terminology
R207.7	Operating Requirements for Power Take-off Drives
S297.T	Full Shielding of Power Drive Lines for Agricultural Implements and Tractors
R314	Implement Power Take-off and Drive Line Pedestal Shafts.
R331T	Implement Power Take-off Lines
R333	Agricultural Tractor and Industrial Tractor Auxiliary Power Take-off Drives

Inasmuch as power take-offs are discussed in other papers, this area will not be examined closely. Suffice it to say that the shields as given in all but one of the standards listed were helpful and are helpful, but do not give full protection. The connecting portions of the PTO, which have the greatest hazard are not covered and many accidents occur as a result. The impression given in literature and the general appearance gives an indication of safety which is not there.

The one standard which does provide for full shielding, S297, is a tentative standard and has not been used on any production model tractor. Other safety features that have been developed will be included in the following sections.

STABILITY

The facts of stability of a tractor are not defined in tractor operator manuals. Any comment about the stability, implies great stability, increased stability, improved stability. It is never stated that the stability is poor or that the tractor is unstable on slopes, etc.

It is the nature of a tractor to tip over backward under certain conditions. The motor power transmitted to the rear wheels in a forward gear can express itself in either of three ways. The wheels can turn, moving the tractor forward, or the wheels can slip. If the wheels are immobilized the tractor will rotate around the axle by the front rearing up and over backward. The relative movement in the axle is identical in all three cases. A tractor has the power to rotate around the rear axles should the rear wheels be held fast. In this situation, if the tractor is in forward gear, the front end will come up, resulting in a backward upset. Such might be the case if you have your tractor stuck in a ditch and fasten a plank or something else to the wheels to get traction. Always back out if you get stuck. Or get someone to pull you out with another tractor.

A tractor can tip over sideways at a speed of 8 miles an hour if the wheels drop into a hole or hit an obstruction (8 mph is about twice as fast as you can walk). It will tip at a much slower speed if you are turning. Slow down and be very careful to avoid obstructions or holes. The chances of upsetting on a turn are four times greater when the speed is doubled.

The chance of a tractor upsetting backward increases if the front end is higher than the back end. This means extra care should be exercised when driving or pulling a load up a hill. The wider the rear wheels are set the greater the tractor's stability. Conversely the narrower the wheels are set the easier it is to tip a tractor sideways. A tractor will tip when its center of weight is outside of its base of stability. The base of stability of a tractor is the area between the effective points of contact of the wheels with the ground surface on which it is operating.

The tractor weight and hitch point on modern rubber tired tractors has been so distributed that under ordinary conditions when operating on level ground with a load either the tractor will move forward with the load, the tractor wheels will slip, or the motor will stop. On hilly or sloping fields this doesn't hold true. A tractor will tip over backward when it takes less power to raise the fron end than to move the wheels. Of course it takes less power to lift up the front end when it is already raised some distance by going uphill or if the back wheels are in a ditch or dug into a hole. When the rear end or drive wheels are higher than the front end the modern tractor will not rear up or tip over backward. However there are some situations where the tractor may tip over backward:

1. The tractor encounters soft ground, the drive wheels dig in and may become lodged or slip easily. Whether this is on the level or not is of little consequence. The rear end drops down and the operator then often disengages the load. If the wheels slip the operator may block or chain the wheels to prevent the slippage. The operator then shifts to low gear, guns the motor, and jams in the clutch. Within a split second, the combined force of full engine power and stored flywheel energy raises the front ot the tractor, it overbalances and tips over backward.

2. The tractor is driven across a ditch and the drive wheels drop into a hole, or an obstruction is hit and the sequence in number 1 then ensues.

3. The tractor is going up a steep incline or pulling out of a ditch. It is started by gunning the motor while in a low gear, and the clutch is jammed in too quickly.

4. A weight is carried on the rear of the tractor which moves the center of weight back nearer or even over the rear axle. This shift of center of weight always results when attached machinery is lifted up behind the tractor. It also results with the hydraulic platform, which is attached on the rear of some tractors. The heavier the load carried the farther back the center of weight is shifted with a consequent reduction of stability.

5. A combination of points three and four. In one accident, a yound boy had a harrow on the hydraulic lift. While on a steep road grade he started in a low gear with a jerk. The tractor tipped over backward pinning him between the tractor and the harrow.

6. The load is attached to the axle or to a drawbar which has been raised too high or cut or set too short. The hitch on the tractor should not be tampered with to change it. The adjustments provided can be used, but it should not be rebuilt to raise its height or to shorten it. The force that causes a tractor to tip over backward is a product of the load and the height of the hitch from the ground surface where the wheel rests. When the hitch is of proper length, if the tractor starts to tip over backward, the hitch lowers rapidly countering this force If the hitch is raised this force is not countered effectively, making the tendency to tip over greater. Also if the hitch is shortened the force is not countered as rapidly when the front wheels rise, and the possibility of upset is increased.[3]

The time required for a tractor to tip to complete instability is very short, especially as compared to human reaction time. With one model of tractor with first and second gear speed of 1½ and 2½ mph tipping time to complete instability was as given in table below:

Tipping Time to Complete Instability[4]

Travel Speed, Gear	1st	2nd	3rd	4th
Tractor level	1.340	0.823	0.614	0.566
Front end high	1.197	0.722	0.577	0.484

The difference between low and second speeds emphasizes the value of the slowest speed for safety in dangerous situations. The true evaluation of this safety factor is unpredictable for any one individual, especially when he is scared or "rattled."

This time element should never be depended upon. With high speeds, instability is reached even quicker. Since drive wheels are usually slipping, one may think he has more time. However, slippage may stop at any one moment. It only takes the equivalent of one-fourth turn of the drive wheels to tip a tractor over backwards.

As mentioned before, a tractor will tip when its center of weight is outside of its base of stability. The base of stability of most tractors is the area between the effective points of contact of the wheels with the ground surface. The exception to this is the wide front wheel tractor, when the front axle is attached to the tractor frame at a definite fulcrum point, as it usually is. The primary base of stability in this case is a triangle, with this attachment point as the apex and the base bounded by the drive wheel effective contact to the ground. Of course, when the tractor starts to tip sideways the front axle, somewhere between the attachment point and the wheel, hits the frame or bump point. This may prevent the tip. It is not dependable. Operators have been encouraged to put too much confidence in the lateral stability of wide front tractors.

High speed with air tires, high clearance and narrow wheel tread combine to make sideways tipping an even greater hazard than backward tipping. A moving tractor tends to continue to move in a straight line. When it is made to run, centrifugal force appears. The centrifugal force of a tractor can be considered to be concentrated at the center of weight.

Centrifugal force is equal to $\frac{ws2}{15R}$.

W is the weight, S is the speed in miles per hour, and R is the radius of the turn in feet. Thus, it is clear that centrifugal force increases very rapidly with speed. If the speed is doubled, the centrifugal force is increased four times. Also the smaller the turning radius, or the sharper the turn, the greater the centrifugal force. For a tractor on the point of tipping on level ground the formula is $\frac{S2}{15R} = \frac{G}{H}$. On the slope

the formula is $\frac{S2}{15R} = \frac{CosA(G-H\ tanA)}{H}$.

S -- speed in mph
A -- angle of slope
R -- radius of turn in feet
G -- horizontal distance, inches, center of weight to side line which is from front to rear wheel point of contact with surface.
H -- vertical distance in inches of center of weight from ground.

These formulas can be used to calculate the speed at which a tractor will be on the point of tipping. Of course a farmer can not do this for every hill and for every load. This is a tool for design. For example, consider a tractor with 90-inch wheelbase, 50-inch tread, center of weight 28 inches ahead of the rear axle, G, 18 inches, h, 32 inches, and R, 9 feet. The speeds at which such a tractor will be on the point of tipping are:

On level ground	8.7 mph
On 20% slope	6.9 mph

These are maximum speeds since the tractor has been considered as a free moving body without the natural displacement effect which would be present on the usual tractor with fuel in the tank, auxiliary steel weights, etc. Also there is no load. These data explain the basic principle of stability. However, in practice we cannot figure the tipping condition for each hill, turn, slope and load. To prevent rear end tips a good rule to follow is: As you sit on the seat, when the front end begins to feel light - STOP.

A wheel tractor may also be upset by one rear wheel going into a hole or over a hump. In one series of tests with 30 tractors the maximum obstacle height varied from 37.67 inches, for wheels set at maximum width, to 5.45 inches with the wheels set in at minimum width. The average was 30.64 inches. The highest and the lowest values for the obstacle height were both for the general purpose tractors of one manufacturer.

Because gravity tends to counteract the shift of weight as one tractor wheel goes over a hump and accentuates it as one wheel goes into a hole, it is more dangerous to drive a tractor wheel into a hole than over a hump of the same size. Rubber tires also accentuate this difference since major tire depression is on the tire going over the hump or into the hole. Speed accentuates the danger of both the hole and the hump.

It is dangerous to drive a wheel over a hump of over 20 inches or into a hole over 16 inches deep, with the tread spread at about 60 inches. If the tread spread is narrower there is more danger of tipping sideways. This is all considered to be on level ground. When driving on a slope, avoid a hump of any size on the uphill side or a hole of any size on the down hill side. With a 60 inch wheel spread, a ten percent slope and the tractor driving along the slope, the tractor is already upset 6 inches.

The most dangerous situation while driving along a slope is to encounter a hump on the uphill side and a hole on the downhill side at the same time. A hole on the downhill side is often encountered when plowing on a sidehill and turning the furrow downhill. With the slope 15 percent and plowing a 8-inch furrow, the lower wheel is 17 inches below the upper wheel. A very small hump on the uphill side in this case can tip the tractor.

The solution thus far developed for this problem is to build an operator protective enclosure. The industry has worked hard to develop such a protective enclosure which would be effective. Sweden and Great Britain did much good work in this area long before our manufacturers were really interested. There are now four standards of the American Society of Agricultural Engineers which effectively and comprehensively define the operator protective enclosure and tests for their competency.

S305.2	Operator Protection for Wheel Type Agricultural and Industrial Tractors
S306.2	Protective Frame Test Procedures and Performance Requirements
S310.1	Protective Frame with Overhead Protection -- Test Procedures and Performance Requirements
S336	Protective Enclosures -- Test Procedures and Performance Requirements

There are two critical questions which irritatingly assert themselves in a study of this area. One is, "Why is so much attention, study and expense expended to protect the operator after the tractor tips, but little to actually preventing the tip?" The other is, "Why is the back-tip talked about and studied more in the field, with very little on side-tip research, when the latter account for about 90 percent of the tips?" It is recalled that when one of the design engineers who worked for many years in this area was asked this last question, he simply answered, "It's easier." Of course we need the operator protection, but we need more activity and production of results in designing to reduce critical stability problems.

BRAKES

With the early tractors brakes were of little importance. The cumbersome early tractors with high rolling resistance quickly stopped when the power transmission to the mobile part was stopped or disconnected. Most steam tractors had no brakes, as we know them, and the first gasoline tractors were built similarly. With the adoption of rubber tires, the development of higher speeds and the reduction of rolling resistance through improved bearings and other moving parts, brakes became a necessity. As size and weight has increased brakes have had to exert a larger and larger force to control the movement of agricultural tractors.

Brakes are used on tractors for three reasons: (1) to assist in making short turns in field operation; (2) for emergency stops; and (3) for parking. Brakes have been involved in many accidents. For operational control in the field the brakes are made to operate independently with two brake pedals, one of which controls the brake on that side of the tractor. On practically all farm tractors, especially the wheel type, there is a means provided to lock the two brake pedals together for road operation and when short turning is not required. The idea being to apply the brakes equally to stop the tractor quickly without turning it. However, the continual individual use of the brakes results in uneven wear and when equal pressure is applied, as when they are locked together, there is unequal braking. This is a great contributing factor to side tips, expecially overturn on the roadway and run off the roadway type of highway accidents. It is necessary to train tractor operators in the safe use of brakes. Always keep both brakes adjusted equally. Some modern tractors have power or hydraulic brakes. Less pressure is needed to operate these brakes, so you need to be very careful in using them until you are thoroughly familiar with their operation.

HITCHPOINT

The hitch, its design, adjustments and use are very closely related to vertical stability and the possible accident, tipping backwards. The early hitches on tractors were not highly designed. The hitch was just a place to attach a load to be moved by the tractor. With the traction power in the rear wheels, that power, in a forward gear, can be expressed in one or more of three ways:

1. The drive wheels turn, moving the tractor forward.
2. The drive wheels turn, slipping on the ground.
3. The drive wheels do not turn and the tractor rears over backward.

The movement in the power train of the tractor is the same in each of the three cases. This tendency of the tractor "to rear over backwards if the wheels can't turn" is both a benefit and a hazard. It is a benefit because it provides the principal way of transferring weight to the rear wheels to increase traction when the tractor needs it for a heavy load. It is a hazard if this tendency to rear over backwards is not controlled, because the tractor will tip over backward.

When a tractor is operating under a light load, it should move easily. This is accomplished by having the weight distributed both front and rear. In general, the weight distribution is one-third on the front wheels, two-thirds on the rear wheels. As the load becomes heavier, it becomes more important to move the load than for the tractor to move easily. The most common cause of failure to move a load is slippage. As the load increases, there is a tendency for the tractor to slow down while power is applied to lift the front end . As the tractor power lifts the front end, the weight formerly bearing on the ground through the front wheels is shifted to the rear wheels, which increases traction. The peak of this transfer of weight is achieved just as the front wheels leave the ground. Operating the tractor so as to lift the front end higher -- in fact, any distance from the ground -- does not increase traction. When there is a load on the hitch, lifting the front end of the tractor actually reduces traction because some of the weight is transferred to the load.

This weight transfer is controlled by the hitch. Hitches are so built on tractors that on level ground the tractor will never rear over backwards. It will do one of the following:

(1) Pull the load, (2) slip the drive wheels, or (3) the motor will die. A hitch of proper height and length prevents backward tips on level ground and controls them to a certain degree on hills.

If the hitch is tampered with, that is, beyond the adjustments given in the Operator's Manual for the tractor, either the efficiency of the tractor in weight transfer or control of the backward tip is reduced. If the hitch is tampered with, the wheels dig in so the front wheels are higher than the rear wheels, or when the tractor is driven up a slope, it may tip even with a load.

A tractor will tip backward when it takes less power to lift the front end than it does to move the load or slip the wheels. The power needed to lift the front end of a tractor is proportional to the distance from a point located by dropping a plumb line from the center of weight of the tractor to a point even with the first point of contact of the drive wheels with the ground or other surface which it is on. Thus, the steeper the hill or the deeper the wheels dig in, the easier the tractor will tip over backward. Also, anything which moves the center of weight toward the rear increases the tendency to tip while anything which moves the center of weight toward the front reduces the tendency to tip backward.

Practices which cause and prevent backward tips

These Increase Backward Tipping	These Decrease Backward Tipping
Driving up an incline	Driving down an incline
Wheel weights	Front weights
Ballast in tires	Lowering hitch with load
Mounted load	Properly hitched load
Raising hitch with load	Reversing when wheels are frozen
Rear wheels digging in	Reversing when rear wheels are in a ditch or in a hole
Using forward gear when rear wheels are frozen	
Driving forward when rear wheels are in a ditch or hole	

Thus we see that many factors affect the tendency to tip back. These include weight of tractor, distribution of weight of tractor, the load, the ground surface, the power of the motor, the slope, mounted loads, mounted equipment, the gear used, the motor speed and the operator. The problem is further complicated because each of these varies from day to day and even from hour to hour.

Many devices have been built to prevent backward tips. These have been built by handy-men and farmers. I know of no device which has been developed by a manufacturer of tractors. The situation is complicated by the fact that it is relatively simple to build such a device for a specific set of conditions. But, with the wide variance involved in farm tractor operations, no effective device has yet been developed. Of those developed so far, by the time the mechanism reacts to control the tip, the power to complete the tip is already in the tractor gears and fly wheel.

Since a mechanical control and not even a warning device, has been developed as yet, the best control today is an alert and trained operator. While sitting in the seat, the operator can sense the backward instability in time to disconnect the clutch if he is watching for it. When the front end begins to feel light as you sit on the seat, that is as far as you should go. Disengage the clutch. What is needed is a sensing device on the front wheels so that when the weight there reduces to a certain minimum, the power is disconnected.

When you hitch your tractor to an implement, always hitch to the drawbar. A load should never be pulled from the axle or seat brace, or from one of the links of a three-point hitch. When this is done there is danger of upsetting the tractor or damaging it or the equipment mechanically.

Check the height of the hitch on the tractor. The height should be 13 to 17 inches between ground level and the hitch point of the drawbar of most tractors. The Operator's Manual has specific instructions for each tractor. With the drawbar at this height the tractor is not only safer for hitching but this is also the safe and standard height for use of the PTO.

HITCHES FOR MOUNTED EQUIPMENT

Most modern tractors are equipped with hydraulic controls for raising, lowering and adjusting rear-mounted equipment. This is why more rear-mounted equipment is used than in the past. Previously, equipment was raised and lowered with long hand-levers and this became quite tiresome.

Rear-mounted equipment is connected to the tractor with "integral hitches." Integral hitches may have one-, two-, or three-point connections between the rear-mounted implement and the tractor. Of these three types, the three-point hitch is the most common. Three-point hitches are standardized so that implements and tractors of different makes and models can be used interchangeably. If your tractor does not have a three-point hitch you can probably get an adapter that will let you use three-point mounted equipment.

SEATING AND PASSENGER ACCOMMODATIONS

Anyone who operated a tractor while sitting on those old "so-called" spring seats and has sat on some of the new seats, knows there has been significant progress in seats. Seats have been man-killers. Most farmers of the past who operated tractors had sore backs all through their lives after a few years of tractor operation. Today many of the tractor seats have general adjustments for weight and height. Most can be adjusted so the operator can reach and operate all controls from a comfortable sitting position for an adult or a growing farm boy of over 12 years of age.

There is no provision for the seating of a person other than the operator on American farm tractors. The usual rule quoted is "no riders". We do have accidents with riders, but it is a small number, less than 5 percent of the fatal, and has not increased with the general increase of tractor accidents. Practically all of these resulted because the injured person was riding in an insecure place, there being no seat provided.

SPEED

It has been said that speed is the number one cause of tractor accidents. Studies suggest this but do not prove it. Speed is involved in all side-tips where turning is involved, as well as in "overturns on the roadway" and "ran off the roadway" tractor highway accidents. However, this is not a high speed in the sense of 30 mph or more. The problem is that the quick short turn in the field, using one of the brakes, while travelling at 2 - 7 mph is an efficiency aid. However, when the same method of turning is used on a road when travelling at 10 - 12 - 15 - 18 mph can just be plain suicide. Speeds up to 15 - 20 mph are very advantageous when moving crops to market and when moving from one farm unit to another. The problem is the combining of unevenly worn or unequally applied brakes with a speed which needs even braking during a quick stop. Of course speeds above 20 - 25 mph should never be used with tractors. The tractor is too unstable for any speeds beyond this.

TRACTOR SAFETY ON THE ROAD

THE PROBLEM

When tractors and other slow-moving vehicles are driven on public roads, four conditions make

TRACTOR + TRAFFIC = TROUBLE

1. Parked in the lane of traffic
2. Operator is a "sitting duck"
3. Operator is half blind
4. Operator is totally deaf

The first is true because of speed differential between the tractor and other traffic. The speed differential is practically the same as that between a parked car and moving traffic. Car speed is from 15 to 70 mph or a span of 55 mph. The range of speed differential is 13 to 68 mph or a span of 55 mph. The slow-moving vehicle to the drive or a car or truck is just the same as parked in the lane of travel. Because of this, we have many collision and side-swipe-from-behind accidents.

Tractor-Car Speed in Miles per Hour

	Tractor Speed	Car Speed	Difference
Slowest speed	2	15	13
Fastest speed	25	70	45
Slowest to fastest	2	70	68

The possibility and probability of tractor accidents on public roads has increased in the past two decades this is due to:

1. Increased auto traffic
2. Increased truck traffic
3. More tractors and more use
4. Larger farms and multiple farm units put tractors on the road more

In one midwestern State, Iowa, there were 5,213 reported accidents with farm tractors on public roads from 1949 - 66. During those years the number of tractors increased 48 percent but the accidents per year increased only 10 percent.

TYPE OF TRACTOR ACCIDENTS ON IOWA ROADS

1949 - 1966

	Total	Fatal	Percent Fatal	Percent of Fatal in type
Collision:				
Motor Vehicle	4,466	91	2.0	21.8
Stat. object	151	28	18.5	6.7
Pedestrian	14	4	28.5	0.95
Overturn on Road	97	35	36.0	8.4
Ran off Road	441	241	54.6	57.85
Other	44	18	40.9	4.3
TOTAL	5,213	417	8.0	100.0

Of all the accidents 85.67 percent of them were collision with other motor vehicles. However, only about one-fifth of the fatalities are in collisions with other motor vehicles. Motor vehicle collisions with tractors have relatively low mortality of 2 percent. All other tractor accidents on the road average 43.6 percent fatal, with overturning, both on and off the road, being 51 percent fatal. These two, overturning on and off the road, accounted for 66.25 percent of all the fatal accidents with tractors and other slow-moving vehicles on the roads. This means that there are two major problems; collision with motor vehicle in nonfatal accidents and overtruning and running off the road in the fatal accidents. Further investigation of nonfatal accidents showed that tipping accidents usually occurred after the operator looked back to see if a car or truck was coming while driving on a narrow country road.

Type of Road on Which Accidents Occurred

(Iowa) 1949 - 66

	Total	Town	Highway	County Road
Collision:				
Motor vehicle	4,466	121	2,334	2,011
Stationary object	151	0	19	132
Pedestrian	14	13	1	0
Overturn on road	97	1	6	90
Ran off road	441	0	7	434
Other	44	1	20	23
TOTAL	5,213	136	2,387	2,690

From the above table, these facts are clear:

1. The problem with tractors on highways is collision with other motor vehicles.
2. Tipping accidents on the road and running off the road are the most prevalent on county roads.
3. Tractor-pedestrian accidents occur in town.
4. Collision with other motor vehicles is a big problem on county roads.

These data are characteristic of most states, especially the Corn Belt States. Collision with motor vehicles accounted for 86 percent of all accidents. The most common collision accidents were collision from the rear, side-swipe from the rear and collision at intersections. All of these accidents result from the motorist recognizing the slow-moving vehicle too late to prevent a collision.

WARNING DEVICES

Many devices have been developed to warn motorists of slow-moving vehicles. Since 1948 Iowa State University, under the supervision of the author, has tested 69 different devices. These have included flags of five colors, six shapes, six sizes, four heights and five positions; reflective tape of four sizes and shapes; eight pinwheels; three whirling bars; the SMV emblem in four different locations and 12 lights of various color and intensity. The SMV Emblem was developed at Ohio State University. Most items were eliminated after road tests showed their ineffectiveness.

During 1964-67, closely controlled road tests were conducted by Iowa State University with the most promising devices. The flourescent flag was included, because so many people think it is good, although previous tests had been disappointing. It was a flourescent orange lastic, 10 by 12 inches. The red and white flag was the same size, but it was of a pliable, porous cloth with alternate diagonal 3-inch stripes of orange-red and white. This type of flag rates well in tests, but it is not recommended any longer because the maintenance problem is prohibitive, and it hangs limp in the rain.

DISTANCES MOTORISTS SEE VARIOUS WARNING DEVICES

(Iowa Tests) 1964 - 67

	Number of Tests	Under 50 Feet	Over 250 Feet	Over 500 Feet	Rating
Flourescent flag	34	76.4%	14.7%	8.8%	0.0
Flashing red light	72	22.4	65.7	58.4	55.0
SMV emblem	797	17.6	71.1	57.3	64.9
Steady amber light	210	16.6	69.5	50.5	64.9
Tractor itself	495	6.1	79.6	59.8	86.6
Red and White flag	41	3.8	85.4	70.7	92.4
Rotating amber light	52	3.8	90.4	78.8	97.4
Flashing amber light	68	1.5	86.7	76.5	98.8

The flashing red light was a standard 4-inch flasher which has been used on many tractors and fulfills the ASAE Standards. The SMV emblem was constructed in accordance with the American Society of Agricultural Engineers standard.

When the flashing amber light and the SMV Emblem were both placed on a tractor, the motorist always saw one or the other at 250 feet or more. No other combination gave such good results.

The tests suggest the use of three safety accessories for slow-moving vehicles on public roads: Rearview mirror located for effective operator use, a flashing amber light and an SMV Emblem. The last two should be so located that the light does not shine on the emblem. When it does it affects its viewing.

REAR-VIEW MIRROR

For a tractor it has been found that the rear-view mirror should be a large one at least 5 by 10 inches, that is adjustable side to side, vertical and tilt. It should be mounted securely to reduce movement. The author has been studying and testing rear-view mirrors since 1955. It was found that most mirrors available on the market have these problems:

1. Bothersome, irritating movement
2. Limited field of view
3. Limited adjustments.

Several models have been developed and field tested. In 1966, 37 farmers field tested the Model No. 52 Rearview Mirror. The farmers were located in 13 States and three Canadian Provinces. The mirror was 5½" x 11" with swivel type telescoping tripod mounting which permitted:

1. Tilt to any degree both vertical and horizontal
2. Adjustment from side to side of 5 feet
3. Adjustment up and down of 3 feet
4. Rigid tightening of all adjustment points to reduce movement to a minimum.

The farmers' reactions to the use:

1. Position used Most:
   Centered - 13%
   to left - 20%
   to right - 67%

2. Movement while used on a tractor:

   Never - 13%
   Little - 34%
   Often - 47%
   Daily - 0%
   Several times daily - 6%

3. How and where was it used:

   Field only 0%
   Road only 13%
   Both places 87%

4. Should the mirror be used on all tractors:

   No - 00%
   Yes -100%

The 37 farmers who field tested the mirror on their tractors operated farms in California, Colorado, Idaho, Illinois, Iowa, Michigan, Missouri, New Mexico, New York, North Dakota, Pennsylvania, Alberta, Nova Scotia and Saskatchewan.

FUEL SYSTEMS

There is not much here to which we need to pay attention. The industry has mostly done a good job in materials and construction in this area. There are two areas which need attention.

Many fires have occurred with farm tractors. It was earlier noted that when a fire occurred and the sediment bulb in the fuel line broke or melted, the fire became uncontrollable for the farmer. What to do about it?

Someone said, "Keep the sediment bulb intact." Another, "Why not use heat resistant glass?" Heat-resistant glass has been used, but I know of no research or tests to show its value for this specific situation. There has been research to prove the value of metal sediment bulbs in this situation. Heat-resistant glass melts at the same temperature as other glass. It is made to be resistant to being heated and then cooled rapidly. Metals melt at far higher temperatures than glass. A few companies are now using metal for this purpose. All should. They were made with glass so a person could see if they needed cleaning out. This occurrence comes more often than with glass.

CONTROLS

Farm tractor controls have become so complex that many farmers operate tractors sometimes for years and never know all the controls. There are two ASAE Standards on controls:

R304 Universal Symbols for Operator Controls on Agricultural and Industrial Equipment.

R335 Operator Controls on Agricultural Equipment and Industrial Equipment.

In spite of these guidelines we still find:

1. A foot clutch on most tractors, but a hand clutch still on some. The clutch may be on either the left or the right. Some have both hand and foot clutches.

2. Brakes are on right or left, sometimes on both sides.

3. The gear shift is at the right, left, in the center, high or low. You find it.

4. Differential lock is located back of the left foot, back of the right foot on the platform or ?

5. The engine controls are found in the front either high or low by the steering wheel; on the steering wheel; hidden under the steering wheel or the dash; or ?

6. Speed controls are to the right, left, high, low, on the steering wheel column, far to the right.

With the controls on a tractor it may be said as it was about gold in the "Gold Rush" days, "The controls are where you find them."

COLOR

With farm tractors color is used as a trademark. It is never used to highlight controls, steps, platforms, seats, bump points and edges or corners, nor to accentuate hazards to alert the operator. In its use color is mostly used with tractors to mask, blank out, hide and confuse. One dealer who proposed to color code tractors he repaired, as a service to his customers, was instructed by the company to desist or else.

CABS

Most of the cabs in use today are death traps or poisoning traps or both. There are a few now which can withstand a tip, but this is the exception. There is not a cab today which is safe to operate in closed while applying pesticides or anhydrous ammonia. Even the so-called pressurize cabs will often in toxic chemicals from the air without it going through filters, ineffective as they are. This is because the air intake is controlled through the fan, but the outlet is not controlled. The cab is built separately and then placed on a tractor. They do not fit perfectly. The fewest number of outlet holes that I have found on any cab and tractor are eight. With multiple outlet and no control, where does the air go out? It might be any one or all of the holes. The probable situation is that it goes out of 1-3 holes. In the process the air rushes over some of the other holes setting up a vacuum action over the hole and the outside air comes in through the hole. If the air contains toxic gases the operator is exposed. In one case the farmer was poisoned with anhydrous ammonia in this way. It came in so gradually that the odor was not noticeable to him. How many farmers are poisoned this way every year?

RECOMMENDATIONS - WHAT CAN BE DONE

In 23 years as a State farm safety specialist and Agricultural safety engineer the writer has investigated thousands of accidents personally as well as analyze the reports of tens and even hundreds of thousands of accidents of farm people. All accidents and especially tractor and machinery accidents have been found to result from the interaction of:

1. Design features of the tractor.
2. Features of the environment.
3. Behavior of the operator.

It is usually possible in any given situation to prevent injury by the complete and necessary control of any one of those factors. Likewise, when an accident occurs, we can say, "If the design had been different and of the proper nature, the accident would have been prevented." Or, "If the environment had been changed in certain essential features, the accident would not have occurred." Or, "If the operator had just done this or that, he would not have been injured." All are true most of the time. We cannot solve our safety problems by blaming someone else. It is our responsibility to continually emphasize that all three components, the machine, the environment, and the operator, are important in safe operation and injury prevention. No one area or group has done all that can be done as long as accidents occur. This is everyone's work, this is everyone's responsibility.

This paper shall now be directed to proposals in the three areas of design, environment, and education and training.

No one is completely committed to safety. However, we expect the other fellow to be completely committed. We cannot pay for the ultimate in safety. There is no justification for inclusion in the ASAE Standards which are written for Engineers, the design engineers, that, "Complete avoidance of accidents ultimately will depend on the care exercised by the operator and others involved." (ASAE R276). These standards and recommendations never get to the farmer operator. Such statements only provide an excuse for unsafe design.

There is no justification for farmers or tractor operators saying, "The manufacturer is not concerned with our safety." This just provides an excuse for their inefficient and dangerous operating practices.

The solution to safety problems with tractors requires a three-pronged attack of:

1. Continuous, vigorous work to design more and more safety into tractors.
2. A recognition by manufacturers, operators and appropriate governmental units that the environment is involved in tractor accidents.
3. A practical yet basic and inclusive training and educational program for all tractor operators.

DESIGN - NEEDS FOR SAFE OPERATION

STABILITY. This area needs some drastic improvements. We not only need improved stability on level and gently rolling grounds, but improved stability to make possible operation on many acres which are too steep for present day tractors. As the press for increased production comes, as it is bound to come, this need will greatly increase.

This needs to be developed in three ways:

1. Increased basic stability through increasing the base of stability of the tractor and a lowering of the center of gravity. The first can be accomplished by dual wheels to increase width and the use of wider axles, as a start. Much imaginative design attention needs to be applied here. Bases which automatically project to prevent tips when the tractor reaches a certain degree of slope, would be very helpful.
2. Improved control of the torque forces, which precipitates backward tips, including definite limitations of hitch adjustment and weight distribution. This should all be related to topography where the tractor will be used. The limitations should be given definitely and understandably in the operator's manual. Warning devices linked to the transfer of weight could be very helpful. These could be such as a warning light or a warning buzzer.
3. Every tractor operator's manual should include definite graphic and understandable explanations of stability and of how tips occur with explanations of the stability limitations of the specific tractor. This should be an

explanation such as given earlier in this paper in the section on stability problems.

GUARDING MOVING PARTS. There is a philosophy that if a moving part is open and clearly seen then the operator accepts the responsibility of the hazard of that moving part. Of course this is ridiculous. Such an idea absolves the manufacturer from any responsibility. It ignores the true situation on the farm of children and of insecure surfaces where falls frequently occur. There is another idea that if the manufacturer provides a guard for a moving part he has fully fulfilled his responsibility on safe design. The adequacy of the guard is not considered. Again this is ridiculous.

Shielding of moving parts should be incorporated into the machine by design not added on by patch. In fact the machine should be so designed that it is inoperative without the shields on moving parts.

As a result of the study of tractor and machinery accidents over a period of 23 years, I submit that shielding should:

1. Be incorporated into the basic design.
2. Interlocked to the power control.
3. Cover all moving parts. Leave functional parts open only to the degree absolutely essential to their function.
4. Complete so even a sleeve or string cannot get in. If it is incomplete, have a decal drawing attention to its deficiency.
5. Use the frame of the tractor as a shield whenever possible. For stationary machines, use a building or other object.
6. Always use the shield. No reason is acceptable for non-use.
7. If moving part is open behind, under or to side of the shield, use d-cals to direct operator's attention to the hazardous area. Explain hazard and avoidance of injury in the operator's manual.

CABS

All cabs should be built to fulfill the needs for roll over protection for the operator. (ASAE S305, S306, S310, S336 in appendix). No cab should be sold which does not provide full roll over protection to the operator. Any roll over accident where the operator is injured as a result of the cab crushing or upsetting, should be bona fide evidence of hazardous design and the responsibility of the manufacturer of the cab.

All cabs should provide toxic free atmospheres for the operator. This will require intake control with appropriate filters for the pesticide, fertilizer or other toxic gas which may be present. It will also require outlet control to prevent the toxic atmosphere's entrance through uncontrolled openings.

In the interim until cabs are made chemical-safe there should be a warning posted in all cabs where the operator cannot fail to see it. This should state something such as, "Warning -- When applying pesticides, anhydrous ammonia or other toxic substances, open all windows and doors."

FUEL LINE AND SUPPLY

The fuel tank and lines should be so located that the heat of the motor will not raise the fuel temperature five degrees Fahrenheit. The sediment bulb should be made of such material which has a melting point of 2000 degrees Fahrenheit or more.

BRAKES

All tractors with possible speeds of over 8 mph should have automatic, self-equalizing brakes with the high speed gears locked to the brakes in such a way that shifting into the high speed gears locks the brakes together. This will provide that application of one or both brake pedals applies braking eqully to all drive wheels.

SEATS

The seat should be so adjustable that the average 12-year-old boy or a fully grown man can sit in the seat squarely and reach all controls handily.

Tractors without driver roll-over protection should have only one seat and no seat belt.

Tractors with roll-over protection and/or roll safe cabs should have an adjustable operator's seat and a passenger seat. Seat belts equal to the highest requirements for automobile seat belts should be with each seat.

MIRRORS

Adequate rear-view mirrors, strategically located to give full view around the tractor, should be on all tractors. If there is no cab, one mirror is sufficient, if it is:

1. At least 5" x 10" in size.
2. Adjustable from side to side (5 feet), up and down (2 feet), and can be tilted vertically and sideways.
3. Supported by a tripod mounting which can be secured in every way to reduce movement to a minimum.

WARNING DEVICES FOR ROAD TRAVEL

Every tractor which may ever be driven on the public road must have mounted on the left rear, as near as possible, the following:

1. An SMV Emblem constructed according to ASAE Standards, ASAE S276. (See appendix)
2. A flashing amber light so located that the light does not shine directly on the surface of the SMV Emblem. The light shall satisfy the requirements of ASAE Standard S307. (see Appendix).
3. Or, have the new type rotating SMV Emblem with flashing light inside. Emblem dimensions and color according to ASAE Standards, S276.

CONTROLS

The ridiculous situation with controls must be corrected. The industry must be required to have a standard location for all controls as well as a standard movement of the various controls. There is no place any more for a hand clutch control. Too many accidents have resulted from their use.

COLOR

All tractors should be colored orange-red so they can be seen easily, on the road. The controls should be colored yellow so they will be easily found and the hazard points highlighted with danger orange (dark).

GENERAL DESIGN FOR SAFETY

All design engineers should subscribe to and practice ethical guide lines of safety in design, such as:

1. Design each tractor and each part as safe as possible.
2. Never decide that the ultimate in safety has been obtained in any design, but strive continually to improve the safety of the design.
3. Highlight, mark or otherwise identify all hazardous parts or locations.

Standards should never provide a means for the industry or the manufacturer to legally practice negligent and/or dangerous and unsafe design and/or manufacture. The practices of a negligent manufacturing group or industry should never justify the negligent design and manufacture by any individual manufacturer.

CONTROLLING THE ENVIRONMENT

There needs to be recognition in operator's manuals and in all training programs that the environment can be involved in the cause of tractor accidents. These elements can often be controlled or guarded against.

Such factors as slope, surface, weather should all be considered and appropriate warning included in manuals and appropriate instructions included in training.

An important environemntal factor in tractor accidents are narrow country roads and highways without adequate shoulders. All public roads should have sufficient shoulders that the tractor can be driven there to allow traffic to pass in the traffic lane.

TRAINING TRACTOR OPERATORS

Training should be provided for both future and present operators. Included in that should be:

1. Model demonstrations of the characteristics of tractors, including: stability, PTO, braking, controls, hitching.

2. Movies, film strips and slides of critical driving situations, accidents which result and prevention of such accidents.

3. Check out on controls emphasizing identification, location, method of movement, result of movement and limitations.

4. Training in and checking out of driving methods in the field, in the yard, on the road and hitching.

5. Trial and practice under supervision.

For new drivers this should be a program of at least 24 hours. For experienced drivers the check out programs could be an afternoon or an evening.

The training and check out programs might be conducted in High School Vocational Agriculture classes, at Farmers Evening Schools, special tractor operator schools, and by Dealers as Tractor Opportunity Nights or Days.

The dealer should see that every purchaser of a new tractor attends one such program the year of the purchase, soon after the purchase or even before.

CONCLUSION

One thousand deaths and 400,000 injury accidents a year in America is reason enough to do something more. We can't do it by blaming others. Manufacturers need to work diligently and continuously to design and build a safer tractor, the public needs to build shoulders on all public roads and educators, manufacturers and dealers must work continuously to train future and present tractor operators to be more efficient and safer operators.

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THE DEVELOPMENT OF SAFETY IN AGRICULTURE AS IT INFLUENCES FARM MACHINERY DESIGN*

We have many responsibilities as educators in the field of farm or agricultural safety. To me, our responsibility is simply stated: To do all we can to improve safety for the farm population. Our primary responsibility, therefore, is to the farmer.

In modern America, the important and increasingly important phase of farm safety is machine safety. Discussion in this paper therefore is limited to that area, pinpointing design as related to safety.

Farm machinery was and is designed to do work, specific work, on a farm, not to keep the farmer safe from injury. This is basic and we must recognize it.

In the design and production of the early farm machines, no thought was given to safety. Any one injury was unfortunate. All were sorry, sympathetic and would flock to help do his work for him.

An injury was the fault of the injured. Not everyone working with a machine was hurt. In fact, the injured had usually worked for hours, days, months, even years without injury. Therefore, since the machine was the same, his injury was the result of something he did or just an unfortunate occurrence, not the fault of the machine. There were such attitudes as:

> Anyone can see that turning shaft and knows enough to keep out of it.
> Any fool knows better than to put his hands in those snapping rolls.
> Be careful -- The life you save may be your own.
> Accidents are a result of carelessness.
> Think -- Machines can't.

Accidents increased. Manufacturers became greatly concerned. They went to work to make machines safer, to reduce the chance of accidents. They organized a Safety Committee as part of the Farm Equipment Institute in 1938.

They developed the standard safety sign to put on farm tractors and machines. The PTO standard was developed with shielding to protect the operator. The hitch was standardized to reduce backtipping. Pyrex sediment bulbs were used to reduce fire problems. Lighting was improved. Standards were developed on these and other safety problems so all machines could be built safer.

Accidents continued. They even increased. Why? Where would it end? These questions were asked by many. They also said, "No one wants farmers to have accidents. We are working at it, doing all we can. Therefore, accidents result from carelessness of the operator, the injured." This attitude is epitomized in a statement found in ASAE Recommendation ASAE-R275 and in its successor, R318, Safety for Farm Equipment and Light Industrial Wheel Equipment: "Complete avoidance of accidents ultimately depends upon the care exercised by the operator and others involved." These standards are not distributed to farmers. Why is such a statement included except to absolve the design engineer?

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*A responsibility of the National Institute for Farm Safety. By: Dr. Norval J. Wardle, Charter President. Chicago - 29 October 1969

Let us look more closely, even critically. Were we, are we doing all we can? Are we doing the right?

The sign, "Be Careful," was developed by the Safety Committee of the Farm Equipment Institute, now the Farm and Industrial Equipment Institute, shortly after it was appointed in 1938. It was a very good step. Look at it:

Be Careful

1. Keep all shields in place.
2. Stop machine to adjust and oil.
3. When mechanism becomes clogged disengage power before cleaning.
4. Keep hands, feet and clothing away from power-driven parts.
5. Keep off implement unless seat or platform is provided.
6. Keep others off.

What has been done with warning signs in 30 years of mushrooming mechanization? The sign today is:

Be Careful

1. Keep all shields in place.
2. Stop engine before leaving operator's position to adjust, oil, clean or unclog machine, unless otherwise specifically recommended in the "Operator's Manual."
3. Wait for all movement to stop before servicing the machine.
4. Keep hands, feet and clothing away from power-driven parts.
5. Keep off equipment unless seat or platform for operation and observation is provided.
6. Keep all others off.
7. Use flashing warning lights when operating on highways except when prohibited by law.
8. Make certain everyone is clear of machine before starting engine or operation.

Very little change of significance except point 7, and it doesn't include country roads where half of the collision accidents with tractors occur. Very little specific warning or identification of specific hazard points on machines. This identification of the hazard points and specifically what to do about them is left almost entirely to the farm operator.

Consider the power shaft shielding. This was important and the industry worked hard at it. In the late 30's and 40's, the PTO standards were developed as well as a standard shield, interchangeable between makes. A great advance. A tremendous safety contribution. Then it was found the shield did not hold up in heavy or abusive use and was often left off. It was made nonremovable, then made integral with PTO. Each was a good move. Little improvement, though, for years. No recognition or warning that it can freeze to the power shaft or that it is not compatible with the master shield or machine stub shield. We have many accidents at these nonrecognized critical points. The standard on full shielding of power drive lines, a good step, was adopted by ASAE in 1966. It has now been changed to a tentative standard. This, I suppose, is proper since no one has used it, to my knowledge.

The sediment bulb demonstrates another way of handling safety. Fires have occurred with farm tractors. It was noted that when a fire occurred and the sediment bulb broke or melted, the fire became uncontrollable for the farmer. What to do about this? Someone said, "Keep the sediment bulb intact." Another, "Why not use heat-resistant glass." Heat-resistant glass has been used but I know of no research to show its value in this situation. If there has been, I would like to know of it.

Shielding moving parts is critical. Practically all shielding is an additive feature. It is rarely complete or adequate; the existing hazard is almost never pinpointed by appropriate specific warning on the machine or in the operator's manual.

As a result of 22 years of machinery accidents in Iowa, I submit that shielding should be:

1. Incorporated in the basic design.
2. Interlocked to the power control.
3. Cover all moving parts. Leave functional parts open only to the degree absolutely essential to their function.
4. Complete so even a sleeve or string cannot get in. If it is incomplete, have a decal drawing attention to its deficiency.
5. Use frame of the machine as shield whenever possible. For stationary machine, may use building or other object.
6. Always use the shield. No reason is acceptable for nonuse.
7. If moving part is open behind, under or to side of the shield, use decal to direct operator's attention to hazardous area. Explain hazard and avoidance of hazard in operator's manual.

We have a long way to go in this area. Universities and many others have failed to see their responsibility and do something about it. Nine universities have hired Extension Specialists in Safety. None hired to do farm safety research or teaching. A few times, research personnel have been authorized to do a small farm safety research project. Two universities have had farm safety courses in the past. One university is now giving instructions to Agricultural Education majors. There have been a few counts of accidents, family report programs, special area checks as in corn harvest, tractor accidents on roads, hot hay control, warning and identification devices for tractors on roads, noxious fumes in silos, power shaft safety. Yet no real continuing research into how accidents occur nor of the development of safer equipment, environment and practices. The Institute of Agricultural Medicine, University of Iowa, is trying to do some pioneer work here. Machinery design research in our universities continues to emphasize function and ignore operator safety. This is on two premises. One - "We will develop the design principle and when industry builds the machine, they will shield it." Two - "Functional components which must be exposed for proper function shall be shielded to a degree consistent with the intended function as it is built."

Industry often ignores safety entirely on new machines. The original idea man, a farmer, handyman, university researcher, industry designer (especially of smaller companies), almost never designs guards on machines. If guards are put on, it is usually a patch-on process. This is justified because the moving component has to be left open or nearly so to function properly. It also has to be convenient for servicing because the careless farmer will take off and leave off the guard anyway.

Machinery accidents results because of an interaction of:

1. Design features of the machine
2. Features of the enviroment
3. Behavior of the operator

It is usually possible in any given situation to prevent injury by the complete and necessary control of any one of these three factors. Likewise when an accident occurs, we can say, "If the design had been different and of the proper nature, the accident would have been prevented." Or, "If the environment had been changed in certain essential features, the accident would not have occurred." Or, "If the operator had just done this or that, he would not have been injured." All are true most of the time. We cannot solve our safety problems by blaming each other. It is our responsibility to continually emphasize that all three components, the machine, the environment, and the operator, are important in safe operation and injury prevention. No one area has done all they can as long as accidents occur. This is our work, this is our responsibility.

THE EVOLUTION OF TRACTOR DESIGN AND SAFETY FEATURES ON FARM TRACTORS

Prepared For Submission
On Behalf Of

The Farm And Industrial Equipment Institute

In Response To A Request
From

U.S. Department Of Transportation
National Highway Safety Bureau

By

Merlin Hansen

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THE EVOLUTION OF TRACTOR DESIGN AND SAFETY FEATURES ON FARM TRACTORS

I. INTRODUCTION

The farm tractor of today is the result of an evolution which has occurred over a period of approximately one hundred years during which time competitive manufacturers of a free society strived to offer products that were acceptable to prospective customers. One hundred years ago, all agricultural production was dependent upon animal or human power. In the U.S.A. today, the use of animal power for agricultural production is practically zero, and human effort is primarily devoted to controlling mechanically powered machines. The farm tractor is one of the basic sources of mechanical power for performing these agricultural operations.

In a free society, each manufacturer recognizes the fact that prospective purchasers will buy the products that they believe best fulfill their individual needs. Therefore, the manufacturer who offers the best performing product, in the eyes of potential buyers, will be most successful. The manufacturer whose products are attractive to few or no customers will be forced out of business. This process automatically gives the buyer the final authority on the performance features that he believes best suit his purposes. It also assumes that the buyer is the best qualified person to judge his own needs.

Traditionally, individual customer performance requirements vary substantially depending upon their individual operating conditions, and upon individual personal preferences. For this reason, tractors produced by a number of manufacturers have always experienced acceptance by a sufficient number of purchasers to warrant quantity production of their products. Also certain manufacturers have failed to update their products to meet customer desires, and have been forced out of the tractor business. In this competitive process, manufacturers continuously develop new and different innovations for their individual products, and submit them to their farmer customers with the expectation of improving their competitive position. In this competitive process, the farmer customer always makes the final decision or choice as to the product features which he believes best suit his individual working circumstances or personal preferences. The foregoing process has been the principal force which has guided farm tractor design since the first farm tractors started replacing animal

I. cont.

and human energy as work sources for performing the necessary functions in connection with agricultural production approximately one hundred years ago. This process of farm tractor evolution is one of the major factors responsible for reducing the manpower necessary for producing this nation's food requirements from approximately 23% of the total population to about 2.3% of the population in the U.S.A. (See USDA Bulletin 233) during the past one hundred years; and at the same time, supplying this nation with more agricultural products per capita than is prevalent in any other nation on earth. In fact, the disposition of an over-supply of food production is and has often been one of the serious economic problems that face the nation.

Throughout the past one hundred years (the period that the farm tractor has been in existence), the conditions under which it is required to operate, and the functions that it is expected to perform have also been and continue to be undergoing constant change. This factor has in the past and continued to influence tractor design to meet these ever-changing circumstances. However, the evolution process of our free society, as previously discussed, has insured that tractor design revisions are made as found necessary, in the eyes of purchasers, to meet their ever-changing circumstances.

II. MAJOR CHANGES THAT HAVE BEEN PREVALENT IN THE EVOLUTION OF THE FARM TRACTOR

In such a basic system of evolution, several important factors are prevalent, namely:

A. Each change was and continues to be evaluated by individual purchasers on the basis of possible reduction in cost of their overall operation, or for the possibility of making their working day more enjoyable. In each case, the proposal is compared with the existing operation.

B. In view of this circumstance, safety features incorporated in products have not been especially emphasized in product advertising; and therefore, it is not uncommon for many people to conclude that safety features are ignored or sacrificed in favor of other features that may have greater appeal to prospective purchasers. The fact that safety features may not have been emphasized in product advertising does not mean that they have been subordinated in farm tractor design.

C. Some groups picture the farmer as an unskilled laborer without sufficient judgment or technical knowlege to properly select the products he purchases and operates. Actually, the opposite is, and has always been the case. The farmer is the most knowledgeable person about the requirements for his own operation. He is a skillful business man, a competent judge of factors which influence his operations, and a responsible person in his neighborhood. If he does not have these qualities, he soon fails as a farmer, and is forced to associate himself with some other occupation.

D. No manufacturer can continue to maintain the good-will of his customers if his product is of a design which subjects his customers to unreasonable hazards; and especially when compared to corresponding hazards that have been prevalent with the previous methods of operation. Furthermore, no responsible farmer can afford to subject himself, his family, or his employees to unreasonable hazards when judged from what has been past practices.

In view of these factors, each generation of farm tractor has incorporated safety improvements over its predecessors. For this reason, both the manufacturers and the users of farm

II. cont.
tractors have constantly made safety improvements for reducing safety hazards to both tractor operators and bystanders. Until the last few years, a multitude of changes have been made without benefit of public fanfare; and have therefore, often gone unnoticed by many people now engaged in safety programs.

It must be recognized that vast changes in farm practices have also taken place during the past one hundred years in order to achieve the productive results previously stressed. A few of the basic changes which have been prevalent in the evolution of the farm tractor include:

A. Replacing the coal, wood, or straw fired boiler along with the reciprocating steam engine with the Otto cycle internal combustion engine as a source of power for farm tractors. This occurred in the period between 1890 and 1915.

B. Making internal combustion engine options available to match economical fuels that were and are offered in various trade areas, namely:

1. Otto cycle engines for distillate.
2. Otto cycle engine for gasoline.
3. Diesel cycle engines for Diesel fuel.
4. Otto cycle engines for LPG (Propane or Propane-Butane mixture).

Options 1 and 2 were generally available when the first internal combustion powered tractors replaced steam powered tractor. Option 3 became available in the early 1930s, and Option 4 became available about 10 years later.

C. Revising the tractor design to adapt it for operating all implements used in agricultural production including seeding, planting, cultivating, spraying, harvesting, and haying tools as well as a multitude of tools used for materials handling and literally hundreds of other basic farming operations. Early tractors were first used for providing power through a belt to operate grain threshing machines; and also for providing power through the drawbar to pull high-draft basic tillage tools (primarily plows). This trend (of adopting tractors to perform a multitude of jobs) started just prior to World War I and continues today.

II. cont.

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Increasing tractor usages resulted in the development of many added features for tractors, a few of which are:

1. Pneumatic rubber tires.
2. The Power Take Off Drive to Implements.
3. The hydraulic control for integral as well as for towed implements.
4. The Universal Three-Point, Draft Responsive Hitch for pulling and carrying implements.
5. Electric Starting and Lighting.
6. Hydraulic Power Steering.
7. Hydraulic Power Brakes.
8. Vehicle Roll-Over Protection as well as varying degrees of operator protection from the sun, rain, cold, dust, noise, vibration, etc.
9. Transmissions with operating speeds increased from one forward and one reverse to eight or more forward and four or more reverse speeds in stepped ratio transmissions as well as infinitely variable ratio drives in forward and reverse.

D. Providing for all makes of tractors to operate all makes of implements within compatible power ranges. This trend started with the original tractors and continues today.

E. Making basic design improvements to secure much more useful power per pound of vehicle weight (from 400 to 600 lb per horsepower prior to World War I to approximately 100 lb or less per horsepower in some vehicles today).

F. Simplifying controls so tractors can be operated by people with very little special training, and simultaneously reducing the physical effort for operating controls to a level which permits operation by female drivers as well as by handicapped or older people. Also, reaching agreement in the industry for uniform vehicle control procedures so

II. cont.

F. cont.

individual operators do not require special training for operating each make or model of tractor. These trends started at the end of World War II and continue today.

THE EVOLUTION OF TRACTOR DESIGN AND SAFETY FEATURES ON FARM TRACTORS

III. MAJOR SAFETY PROBLEMS PREVALENT IN THE EVOLUTION OF FARM TRACTORS

Most people are generally aware of the aforementioned major improvements that have occurred in farm tractor design over the years. The increases in food production resulting from these changes are also common knowledge to most people because these factors have received wide publicity from many sources. The improvements in product safety that have accompanied these changes for greater productivity are not as well publicized; and therefore, may not be as well understood by many people. It must be understood that safety features as well as any other performance features become production items in products produced in our free society when two conditions are fulfilled, namely:

A. When a sufficiently large percentage of purchasers appraise the feature and consider it to be worth its cost by improving the performance of the machine as compared to the previous practice.

B. When manufacturers find it possible to develop and produce a practical design that achieves the desired result at a price that a sufficient number of buyers are willing to pay.

This situation simply means that buyers must concur that an unreasonable safety hazard exists in an existing design, and manufacturers must develop a practical solution to the hazard at a price acceptable to the buyer before the safety feature will gain general acceptance. Since both the farmer (buyer) and the manufacturer are knowledgeable people, their joint appraisal and solution to safety hazards have been sound.

The ever-changing circumstances under which tractors are used requires that safety provisions must be constantly re-evaluated and revised to meet the ever-changing operating circumstances. The voluntary system which has governed farm tractor design since the inception of farm tractors has been sufficiently flexible to respond to these changing conditions. A list of some of the major safety features that have resulted from this process of evolution are:

A. Beginning with the introduction of the first farm tractors, the machines that they were required to operate were often produced by different manufacturers than produced the tractor. This circumstance continues to be the case today, and is responsible for the voluntary industry effort of providing for all makes of tractors to successfully operate

III. cont.

A. cont.
all makes of implements within power limitations. Since the internal combustion engine is not as flexible from the standpoint of operating speed as was the steam engine that it replaced, and since a major use of these early tractors was to furnish power for belt driven harvesting machinery, it became necessary to establish an industry standard for belt speeds. A tractor which provided power at an incorrect belt speed for a particular machine resulted in improper machine performance; but furthermore, if the belt speed is too high, a hazardous condition is encountered in the area of the driven machine. These circumstances caused the industry to recognize the need for a Standard covering Tractor Belt Speeds which in turn was established in 1917. (See SAE J720. It was also later recognized by ASAE as their number S210.)

B. With the evolution of the Power Take-Off Drive in the early 1920s, the industry also recognized the need for establishing standards governing operating speeds, dimensional relationships, permissible load limitations, and adequate shielding of the operator from moving parts to secure a reasonably safe environment for the machine operator. It also recognized the requirement for all makes of tractors to operate all makes of implements within compatible horsepower ranges. Consequently the first Standard covering this item was established in 1923 and others have been added later as the PTO drives and the circumstances under which they operate became more complex. (See especially SAE J718 or ASAE S213, SAE J719 or ASAE S204, and SAE J721 or ASAE R207.)

C. As the farm tractor was developed further to adapt it to planting, cultivating, and harvesting of row crops such as corn, cotton, soybeans, as well as a multitude of vegetable crops, it became necessary to equip the tractor with a system of independent braking for each rear wheel in order to secure sufficiently aggressive steering to successfully perform these operations. This feature allowed the operator to apply brakes to either rear wheel independently, and thereby supplement the steering effort secured by the front wheels. This feature provided the necessary steering effect to properly control the tractor in performing the abovementioned row crop farming operations. Consequently independent rear wheel brakes were incorporated in practically all tractors produced for such farming operations by the late

III. cont.

C. cont.
1920s and the early 1930s. Up to this time, maximum practical travel speeds for steel wheel equipped tractors were in the range of four to five miles per hour. However, the development of pneumatic rubber tires for tractors made farm tractors adaptable to performing additional agricultural jobs such as hauling loads on rubber tired wagons, transporting over substantial distances from one field to another as farms increased in size, and pulling certain field tools such as rotary hoes, sprayers, etc., some of which have been developed to function successfully at the higher travel speeds of 6 to as high as 20 miles per hour. By the late 1930s, practically all farm tractors were equipped with transmissions which permitted effective performance with operations utilizing travel speeds in the range of 15 to 20 miles per hour. The combination of independently operable rear wheel brakes along with the higher travel speeds created a safety hazard if the operator failed to apply the brakes of each rear wheel evenly when he attempted to stop from the faster travel speeds. Under some conditions of terrain, the aggressive application of one brake might cause a vehicle upset. This circumstance was recognized by the industry, and provision for optional equalized rear wheel brakes as well as for the ability to apply the brakes individually, if desired, was incorporated in most agricultural tractors by 1960. Industry standards (SAE J841 or ASAE R335) adopted in 1963 specified provision for equalizing tractor brakes.

D. Prior to World War II, operating farm tractors and related machinery was generally performed by able bodied men. The tractor was in the process of replacing animal power for performing farm operations and able bodied men were required to handle the draft animals and related farm machinery. Therefore, tractors prior to this period had conditions of operator environment, comfort, and strength requirements for operation of controls similar to what was prevalent with machines that tractors replaced. Furthermore, during and immediately following the 1930 depression years, farmer customers simply did not have the financial ability to purchase any tractor features that did not contribute directly to productive and economical food production. However, by the start of World War II, the farm economic circumstances eased somewhat; and also farm labor shortages rapidly became severe. These factors made it obvious to the industry that customers would find it to their advantage to buy improved

III. cont.

D. cont.

operator environment for their tractors in order to:

1. Permit the tractors to be operated by females or older persons who had less physical strength than the former able-bodied male operator.
2. Provide a more comfortable environment for the operator and thereby attract labor that would have found employment elsewhere under more comfortable conditions.
3. Provide for using operators having less skill or little previous training.

These circumstances prompted the use of power steering, power brakes, and other controls requiring less physical effort than was previously prevalent. It resulted in cushioned operator seats with greater consideration being given to more comfortable seat suspension characteristics, and to making provision for easier mounting and dismounting from tractors. It also prompted more effective positioning and more natural directions of motion for controls. Greater attention to shielding the operators from moving tractor components became important because of the large percentage of less experienced or minimum trained operators that farmers then had to depend upon. These circumstances also started the trend toward better operator protection from heat, sun, wind, dust, etc. It also revealed the need for uniformity of vehicle controls between makes and models since trained operators for individual models simply were frequently not available. Even people unfamiliar with the local language were and still are often recruited as tractor operators. These factors prompted the development of industry standards covering:

1. A uniform system of operator controls in 1963 (see SAE J841 or ASAE R335).
2. A system of uniform operator symbols in 1967 (see SAE J389 or ASAE R304).
3. A list of safety features that should be considered in the design of farm tractors in 1966 (see SAE J907 or ASAE R318).

III. cont.

E. With the greater use of farm tractors on public highways which was made possible by the development of pneumatic rubber tractor tires in the early 1930s, the matter of adequate safety marking and lighting became important. The farm tractor and its related machines are now recognized by law enforcement groups as posing distinctive problems which prohibit them from practially complying with lighting specifications established for on-highway vehicles. The farm machinery industry have worked cooperatively with the National Safety Council and U.S. Committee for Uniform Traffic Laws and Ordinances on this problem. As a result of this effort, the Uniform Vehicle Code now carries specifications for farm tractors and related machinery when operated on public roads. The following industry standardization documents have also been developed specifying the required items of lighting and marking:

1. Lighting and Marking for Agricultural Equipment was first adopted by ASAE in 1954 and later updated in 1964 (see ASAE S279 or SAE J908).

2. Slow Moving Vehicle Identification Emblem adopted in 1964 (see ASAE S276 and SAE J943).

3. There are several additional standardization documents covering more detailed specifications for the various components that are used in the complete system.

F. As a result of accident data collected and compiled by the National Safety Council, a number of state safety agencies, and the United States Department of Agriculture in the late 1950s and the early 1960s, the matter of operator fatalities and injuries resulting from accidental vehicle upsets became apparent to the industry. The industry immediately engaged in an exploratory program to determine means of providing operator protection in the event of accidental vehicle upsets. These studies revealed several important and significant points, namely:

1. Farm fatalities due to tractor upsets is by far the greatest single cause of fatal accidents occurring with farm machinery operation. Slightly over 500 fatalities per year due to vehicle upsets are prevalent with approximately 4-3/4 million tractors in operation in the U.S.A., or one fatality per year to approximately 10,000

III. cont.

F. cont.

1. cont.
   tractors in operation.

2. Both rearward and sidewise upsets are prevalent in both fields as well as on public highways.

This study included active cooperation with the National Agricultural Institute of England, the National Swedish Testing Institute for Agricultural Machinery, as well as other overseas groups who had background experience in providing protective devices for farm tractors in their countries. Advantage was also taken of the experiences of the American passenger car manufacturers in connection with their high speed roll-over tests and their high speed barrier collision tests. The experiences of these groups proved most helpful in establishing realistic and reasonable testing procedures for evaluating the design of protective frames for tractors used in the U.S.A. However, the overseas experiences on tractors were not directly applicable to U.S. circumstances because the popular tractors in this country are larger and heavier than those prevalent overseas. Further, a vast number of integral implements are used with agricultural tractors in this country. Any roll-over protective frame must be compatible with most integral implements and all popular implements in order to secure reasonable customer acceptance of the device in this country.

Starting early in 1962, manufacturers of farm tractors in U.S. initiated studies to develop roll-over protective frames for their individual vehicles. The various companies cooperated with each other by freely exchanging test information secured through their individual efforts. Uniform test procedures which provide reasonable degrees of protection for tractor operators in the event of an accidental vehicle upset have been developed and agreed upon in this country. The following standardization documents are now established defining performance test requirements:

1. Operator Protection for Wheel Type Farm Tractors adopted in 1967 (see ASAE S305 or SAE J333).

2. Protective Frame Performance Requirements adopted in 1967 (see ASAE S306 or SAE J334).

III. cont.

F. cont.

3. Protective Frame With Overhead Protection - Test Procedures and Performance Requirements adopted in 1968 (see ASAE S310 or SAE J167).

4. Protective Enclosures - Test Procedures and Performance Requirements adopted in 1970 (see ASAE S336 or SAE J168).

The industry introduced the first production designs of protective frames to the trade in the fall of 1966. By 1970, protective frames had been made available to the trade for practically all current production models of tractors as well as for some of the non-current models. As a general rule, these frames are offered with varying degrees of protection, namely:

1. A structural frame only.

2. A structural frame plus a sunshade.

3. A structural frame plus overhead protection from falling objects. (This option is usually offered only for vehicles used in light industrial or forestry operations.)

4. A structural frame plus a complete enclosure and with or without heating, cooling, air filtering, etc.

Four years of experience with customer owned and operated vehicles equipped with these safety frames reveal conclusively that they are effective in reducing fatalities in the event of accidental upsets. In fact, there are no known incidents of an operator fatality with one of the tractors equipped with a protective frame meeting the specifications specified in aforementioned standards. It is also very evident that customer purchases of protective frames which provide only roll-over protection is practically nil. There is an increasing market for the frames with additional weather protection, and with the complete enclosure or cab being the most popular option. However, in the neighborhood of 20% of production vehicles are currently being shipped with some type of roll over protection.

The foregoing discussion described in considerable detail several important safety features now offered for farm tractors. Other

III. cont.

important safety items of general interest include:

A. Electric starting.

B. The Three-Point, Draft Responsive Hitch.

C. The Quick Coupler for the Three-Point, Draft Responsive Hitch.

D. Safety switches to prevent starting the engine with the tractor in gear.

E. Non-skid tread for steps, foot pedals, etc.

F. Proper hand rails and guards for mounting steps.

G. Shielding the operator from moving parts.

H. Hydraulic Remote Controls for Towed Implements.

I. Spark arresters for internal combustion engines.

J. There are many additional items that can be listed.

Further, the following list of important safety items are under study by cooperative industry groups at this time:

A. Safety chains for towed vehicles.

B. Minimum braking requirements.

C. Exhaust emissions.

D. Noise levels.

E. Seat performance testing procedure.

During the foregoing discussion, reference is frequently made to industry standardization documents. It is not uncommon to conclude that establishing certain specifications in a standardization document automatically solves the particular problem. This is a false assumption because compliance to standardization documents in our free society is entirely voluntary on the part of each user. Further, no manufacturer can afford to make his product conform to an industry standardization

III. cont.

document unless he is confident that his customers are willing to accept his product as produced in conformance with the particular industry standard. Unless this goal is achieved, the standardization document will not receive compliance by manufacturers or acceptance by users, and its value as a means for preventing injuries is worthless.

The standardization documents referenced in this report were developed by knowledgeable people in industry whose judgment indicated that the buying public would accept products made to the standards. In the rare instances where the buying public rejected products specified by an industry standard, the industry representatives responsible have acted promptly and established revised specifications that do receive public acceptance.

Voluntary industry compliance to standardization documents referred to in this report is excellent. This is achieved because these standardization documents (as previously stated) are primarily developed by knowledgeable people from industry in cooperation with knowledgeable people from other segments of society who have some responsibility or exposure to the problems encountered.

IV. MANUFACTURERS' PRODUCTS MUST BE ACCEPTABLE TO CUSTOMERS

A study of events which have occurred in the farm tractor industry are rather conclusive that the manufacturers have developed and offered those features in their tractors that their customers desire and are willing to buy. This applies to all types of performance features as well as to safety features. There are also instances where manufacturers have offered certain features, and customers simply refused to accept them because they were too expensive, or too cumbersome to use, or interfered with the operating efficiency of the machine, or for some other reason. A few examples are:

A. Rear wheel fenders for row crop type tractors from about 1935 to 1962 or 1963.

B. A flashing warning light that was transferable from one implement to another and was for use when such machines were operated on highways after dark.

C. Some designs of power take-off drive line shielding.

It is evident that some individuals seriously believe that necessary safety features for farm tractors must be specified and enforced by government edict, because these people do not consider the farmer user to be knowledgeable or competent enough to judge his own requirements. Others seem to believe that these safety features are not included on machines because manufacturers simply refuse to furnish them.

Forcing the sale of safety features on unwilling buyers has, in the past and continues to be, a waste of economic wealth of this nation. If the user is not convinced from his own experience and judgment that the safety device is necessary, he will not maintain and use it even though he may be required to buy it. In such cases, there is insufficient law enforcement officers in this nation to enforce the use of such safety features, since their use is primarily on the farmers' private property. Typical examples of such devices which were originally developed in good faith, and in some cases were specified by law are:

IV. cont.

A. Red electric tail lights for tractor drawn farm wagons and related implements.

B. The transferable red or amber warning light for tractors and farm machinery.

C. Fenders for row crop tractors in the period between 1935 and 1962.

D. The old tunnel type PTO shielding.

E. Seat belts for tractors.

In each of the above cases, manufacturers have offered or do offer the items in question. Items A, B and C were (for a period) made legal requirements for the sale of machines in certain states. Still the beneficial results of their use was nil because they never received customer acceptance.

THE EVOLUTION OF TRACTOR DESIGN AND SAFETY FEATURES ON FARM TRACTORS

V. COOPERATIVE ENDEAVOR IN THE FARM TRACTOR AND FARM MACHINERY INDUSTRIES.

In achieving the advancements in farm tractor and farm machinery that has been accomplished since tractors were first offered to the agricultural industry, it became self-evident to those originally responsible for leadership in this program that some problems could not be solved by a single manufacturer. Instead, the cooperative efforts of a number of tractor manufacturers as well as of related industries had to be combined in order to reach acceptable solutions for some important common problems. Even though our competitive system of free enterprise requires that each manufacturer must work independently on improving his own products so that they display certain points of superiority to his individual customers, there are certain common problems whose solution depend upon common effort by a number of segments in the industry. This simply means that the engineering staff responsible for the product design of any manufacturer must put forth all possible effort to make his product superior to those of his competitors in areas of competitive enterprise; but at the same time, he must work diligently and use all of his technical skills while working with corresponding individuals from competitive organizations toward developing sound solutions to common industry problems. Through the process of evolution, a system has developed which achieves these goals.

Problems which are recognized as being common to the entire industry include:

A. Providing for all makes of tractors to function with all makes of implements within comparable power ranges.

B. Solving safety problems resulting from the use of various combinations of implements and tractors.

C. Reaching agreement on uniform performance testing and rating procedures.

Any satisfactory solution to the above mentioned problems must be acceptable to:

A. Most tractor manufacturers.

B. A vast majority of implement manufacturers whose products are required to work with the tractors.

V. cont.

C. The individual who will purchase and use the end product.

A cooperative system has, therefore, evolved over the years which does fulfill these goals. Over the years, the technical and professional representatives have identified and agreed upon common industry problems when they became apparent. These same people have freely exchanged information and have worked diligently in a friendly atmosphere of mutual confidence in the integrity of each other while developing sound solutions to these common problems. The present cooperative setup includes:

A. Technical committees composed of knowledgeable people recruited primarily from industry. These people through their background of experience also have reasonably good judgment as to what will be acceptable to prospective customers. They will realize that any solution must eventually be accepted by their customers. These committees submit their proposals to one or more of the recognized standardizing bodies for consideration as standardization documents.

B. The review of the recognized standardizing bodies include appraisals by larger segments of society.

C. At present, the process of developing and securing approval on standardization documents, and especially those influencing product safety, including technical input and evaluation by knowledgeable and skillful people recruited from those areas where the necessary skills are available, including:

1. Tractor manufacturers.

2. Farm machinery manufacturers.

3. Manufacturers of accessories and hardware items.

4. University people engaged in extension or research endeavor on a particular subject.

5. USDA or other government people engaged in research endeavor on a particular subject.

6. Safety Organizations such as the NSC and NIFS.

7. Professional Societies, especially SAE and ASAE.

V. cont.

C. cont.

8. Other knowledgeable groups who can contribute their skills to the particular problem, such as insurance groups, farm organizations, etc.

Groups as found necessary to solve particular problems have and continue to be recruited from the appropriate areas listed above. Such groups have demonstrated their ability to reach sound and acceptable solutions to joint industry problems.

THE EVOLUTION OF TRACTOR DESIGN AND SAFETY FEATURES ON FARM TRACTORS

VI. RECOMMENDED POLICY

The following policy is, therefore, proposed (as a result of observations pointed out in the foregoing discussion) for handling this problem:

A. In any public area, the government has a distinct responsibility to establish regulations which protect the safety of *all people* who have a right to use such areas. It follows, therefore, that laws should be *adopted* and *enforced* which protect the safety of *all people* on public roads against hazardous circumstances created by anyone. If this pilosophy is accepted, the several responsible legislatures should establish, and law enforcement groups should enforce such laws governing operating procedures, adequate safety marking and lighting, and other appropriate safety rules deemed necessary for farm tractors when operated in public areas. Substantial and constructive progress has been achieved in this regard, but it should be continued. Law enforcement groups should be capable of enforcing such legal requirements in public areas.

B. The government *should not* assume the responsibility to protect each person from harming himself because of committing a foolish, careless or irresponsible act. We must remember that there is no substance, no product, or no process that is always absolutely safe, or that will not injure or kill a person unless proper precautions by the user are observed. Items in everyday use such as water, fire, rocks, soil, hand tools, ladders, etc. are classical examples. The individual must learn to handle all items properly or suffer the consequence. The government cannot and should not attempt to insure protecting each individual when he is not endangering others in a public area.

C. No government agency should force their services onto a segment of our free society unless such services are asked for by a group of actual users. It appears that a great deal of the existing programs for government intervention between industry and consumers are not being requested by a representative majority of the consumer group in question. Instead, government bureaucrats in their zeal to increase the activities of their sections are actively influencing certain consumer groups to press for their assistance,

VI. cont.

D. Continue to strive for further improvements in product safety as well as for continued advancements in other performance features to meet ever-changing conditions prevalent in the agricultural industry. This can most effectively be accomplished by continuing to encourage progress through the process of evolution that has in the past resulted in providing the U.S. farmer with the most effective line of farm machinery on earth. The product safety efforts under the existing system would be improved and strengthened if it were supplemented with more accurate and more complete data from farmers relative to injuries and fatalities that are experienced by those associated with the operation of farm tractors and related farm machinery. It is believed that the Federal government could be of best assistance by supplying this type of service.

Note: Copies of the industry standardization documents listed in Section III of this report are attached as reference material.

Merlin Hansen/rh

TRACTOR TO IMPLEMENT - POWER DRIVE SHAFTS

Prepared For Submission
On Behalf Of

The Farm And Industrial Equipment Institute

In Response To A Request
From

U.S. Department Of Transportation
National Highway Safety Bureau

By

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A-107

TRACTOR TO IMPLEMENT - POWER DRIVE SHAFTS

BACKGROUND

Historically, the individual manufacturers have taken heed of the customers' need for safety in power drive shafts.

A tractor by itself can serve no purpose other than transportation for its operator.

A power take-off driven implement can serve no purpose unless coupled to a power source.

This writing deals with the method, mode and safety of transmitting the power from the tractor to the implement. Your attention is called to the fact that modifications and improvements made by the individual manufacturers are done so as to provide safety and machine interchangeability for the user whereas the producer of equipment has had no material gain by providing these features.

In the early days, the mode of this power transmittal was by an open belt which could have been, as in the case of a stationary thresher, at least 25 feet between the power source and the driven implement; no guards over the belt nor pulleys, both were totally exposed. The belt was extremely heavy and even when a man stood clear, if the belt broke or jumped off the pulley, anyone in line with the whipping leather was in extreme danger. Belt pulley drives on wheeled tractors were as much a part of the tractor then as the power take-off shaft is today. However, power transmittal is where the similarity of these two systems ends.

Through evolution and engineering, the implements left the stationary stage of operation in the farm yard to become field-going machines. This meant that the power to be transmitted had to go through a drive line which was capable of any gyration imaginable. It had to take power around corners at angles up to 90°. It had to be capable of permitting the machines to follow ground undulations -- it had to shrink in length when tractor and implement came closer together and had to expand in length as the machines separated, all this while transmitting the power of the tractor to the implement. This has been accomplished through the use of a telescoping universal joint shaft and brings us to the activity of the individual manufacturers in a continuous program to provide safe operation and functioning of this drive line.

PROTECTIVE SHIELDING OF THE POWER DRIVE SHAFT

Recognizing the need to protect the operator from contact with rotating shafts, the engineers provided a "master shield" for the tractor PTO shaft, this shield being capable of accepting another shield which housed the connecting drive line back to the implement. Initially these were "tunnel" type telescoping shields, which were shaped in an inverted "U" and which provided protection on 3 sides of the revolving shaft, leaving the bottom open. These shields were adopted by the individual manufacturers during the 1920's.

Normally, providing these shields should fulfill an obligation to protect against a hazard, but because the tractor to implement shield could be removed from the tractor and/or the implement by a quick-attach spring-loaded latch, it was often removed and never replaced, either intentionally or because it could not be found when needed. This then left the revolving shaft exposed as a hazard. Individual manufacturers recognizing this shortcoming then made the shield an integral part of the implement by fastening it with a rivet or other more permanent means, thereby making it difficult to remove and, although many users complained because servicability often was more difficult, it did contribute towards the availability of the shield when coupling the implement to the tractor.

Even though we had provided a shield which was a relatively permanent part of the coupling members, we sought ways to improve on our design, paying particular attention to covering the exposed underside of the "tunnel shield" and decreasing the exposure of the universal joint when the centerline of of the tractor and the implement were at an angle to each other. From these studies evolved the full-housing rotatabile bell-end shield which is journaled on the drive line and free to revolve independent of the drive line. Should an object come in contact with the shield, the shield becomes stationary even though the drive line continues to rotate. By having the shield rotate, when no obstruction is encountered, it provides persons in the vicinity with a warning that there is a hazard of a rotating shaft, but should the warning be ignored, the shield provides protection by becoming a non-revolving member, if contacted.

The bell-end portion of the shield provides greater coverage of the universal joint which permits taking power around corners at infinitely variable angles. This is possible because it is an integral but individually journaled member of the drive line.

The type of shielding described above is specified in the Agricultural Engineers Handbook and the Society of Automotive Engineers Handbook under Standards ASAE S203.7 and S204.6 and SAE J-718 and J-719 and reference to these standards are in other standards of both publications.

The individual manufacturers have taken additional steps towards further improving the power drive line shields and they are described in ASAE S297T and SAE J955. The "T" after the standard designation means this is a "tentative standard". The reason it is not a fully adopted standard is because the type of shielding described in the proposal has not yet been fully developed and thoroughly tested; therefore, none are commercially available at this time. There is every indication such shields will be available in the near future. Several various designs are being tested by members of our industry, as well as the producers of drive lines. Designs consist of spherical sliding members or plastic covers over the universal joints. We are all aware that any concept developed must be applicable to existing tractors and implements and cannot be unduly expensive to the customer. However, by adopting this "tentative standard", we are forcing ourselves to continue to search for safer drive line shielding, even though at the time of adoption of the standard, we were not totally knowledgeable as to how this might be accomplished.

ESTABLISHMENT OF LOAD LIMITATIONS ON DRIVE LINES

Mechanical failures may result in creating a hazardous environment. This is true of all man-made situations or machines. Any article engineered and produced by man can be abused and a failure can be created. We in the agricultural and industrial field have taken and continue to take positive action to prevent such failures from occurring.

Referring again to the power take-off of the tractor and the drive line to the implement, we have imposed certain guide lines and restrictions upon ourselves to protect the user, even though unintential or intentional abuse of the equipment may take place. These safeguards are "built into" the machine provided and the user may not even be aware of the fact that his safety is being protected by these safeguards.

The SAE and ASAE standards previously referred to establish many dimensional limitations which prevent overloading of the drive lines.

The tractor to implement hitch points are clearly defined and the manufacturer strives to abide by these restrictions. Instruction books inform the user of proper coupling of tractor and implement. Decals are provided on the equipment. The Farm and Industrial Equipment Institute has had promotional programs to provide instructions on proper dimensional hitching. Farm equipment manufacturers, their service organizations, and their dealers have all cooperated in publicizing and distributing information and instructions on proper hitch geometry. Nevertheless, if decals, owners manuals and instructions are ignored by the user, inadvertently or otherwise, mechanical interferences can take place and, although in operation, there is a warning by excessive vibration and sound; should these signs be ignored, failure of a drive member can take place with the possibility of creating a potential safety hazard.

Certainly we recognize this potential hazard and although we have studied other means of transmitting this power (electrically, hydraulically, individual power units) we have been unable, as engineers, to provide a means which can match the power take-off drive line and still meet the practical functional requirements and economical demands of the purchaser. Hydraulic transmittal of power appears the most logical at this time, but in the higher horsepower requirements of our ever-growing higher-capacity machines, the purchaser might not accept a monetary penalty of a large hydraulic pump and motor as compared to a drive line. For a high powered drive, this cost penalty could be a ratio on the order of 50 to 1, plus the possible cost of multiple hydraulic motors for various implements which he may prefer compared to removing and reinstalling the hydraulic motor each time he changes his farm implement for a different field operation.

In July 1954 an electrical drive from the tractor to the implement was placed on the market by one full line manufacturer, but was not accepted by the trade and was discontinued in September 1960 because of:

1. **Electric generators and motors of high horsepower are impractical for this field-going operation.**
2. **Sufficiently high horsepowers could not be developed by practical generators.**
3. **System was inefficient due to transforming combustion engine energy into electrical energy and then to mechanical implement drives.**

4. Electric power of high voltage creates entirely new safety hazards with which the user may be totally unfamiliar. Electricity cannot be seen and, therefore, the user is totally unaware that a hazard may exist.

We do, nevertheless, look forward to the future when, through new materials, productive methods, and high volume, we will be able to eliminate the drive line as we know it today. We, as an industry, already utilize the hydrostatic drive in tractors and self-propelled machines and, although more expensive than gear drives, it is within reason because of the elimination of portions of the expensive traction drive and the advantage of infinitely variable ground speed, which also contributes to safer operation of implements (to be discussed later).

Additional factors which contribute to safety have been adopted by the ASAE and SAE are also defined in the referenced standards. These factors establish 540 and 1000 revolutions per minute as the designated speed of the power take-off shaft of the tractor (depending upon the power to be transmitted). Initially the standards contained only the 540 RPM standard, but as demands created a need for higher horsepower transmittal the individual manufacturers recognized that the low speed of 540 RPM could not transmit the higher horsepower torques and therefore to prevent potential mechanical failure and resultant potential safety hazard, the 1000 RPM standard was adopted in 1958. This answered the immediate problem, but to make the operation of a tractor most economical for the user, and because some of the tractor increased power was derived from higher engine speeds, it was necessary to establish the PTO shaft speeds at some point less than wide open throttle. In addition, it was found that the users learned that by changing governed speeds of engines, they could acquire greater horsepower, particularly when the tractors were used for pulling draft loads, such as plowing, and in that way increase ground speeds. Again to protect the user from potential danger in running PTO equipment at over speed the individual manufacturers recommended as published in the SAE and ASAE standards that any tractor capable of exceeding the PTO speed be equipped with "...an instrument indicating the normal speed of the PTO shaft when operated under load...". This instrument depended upon the operator to look at a dial and establish engine speed when a pointer indicated proper PTO speed. Once again we found certain operators ignoring this precautionary measure which then forced the individual manufacturers to protect the operator by adding to that same standard an additional safeguard which is defined as follows:

> "In addition, tractors as described above shall be equipped with means to prevent the operator from inadvertently operating the power take-off shaft in excess of 630 RPM (for the 540 loaded speed) or 1150 RPM (for the 1000 loaded speed) under no load conditions."

Here again, this was done to protect the operator inadvertently creating a safety hazard to himself.

The tractor and implement combinations are tools by which the user earns his living. Consequently, he demands the most efficient combination of equipment for his needs. In recent years farm fields have become larger and due to economics and the shortage of labor, there have been demands for ever increasing horsepower so that one man can accomplish more work. Recognizing that this increase in power can be transmitted through the power take-off shaft, individual manufacturers decided that to prevent mechanical failure it would be necessary to strengthen the power transmittal members. The original PTO standard listed only a 1-3/8" diameter 6-spline shaft at 540 RPM. To compensate for the higher horsepower, the standards now list a 1-3/4" diameter at 540 RPM, a 1-3/8" diameter shaft at 1000 RPM, and a 1-3/4" diameter shaft at 1000 RPM. The coupling splines on each of these shafts were made non-interchangeable in order to match the power requirements of an implement to the output of the tractor. In addition to matching shaft sizes and speeds to power output and power absorption, ASAE R207.7 and SAE J-721 specify maximum bending and torsional load limitations permissable for transmittal and, if necessary, overload protective devices are to be provided by the manufacturer when it is possible to exceed the specified maximum loads.

A recent new tentative recommendation adopted by ASAE, number R331-T, was adopted to establish six sizes of universal drive lines from the tractor to the implement. The purpose in establishing these six categories was to identify by class size the load carrying ability of each of the six sizes. The reliability, dependability and minimum life and load capabilities are specifically set forth by test requirements. By having these categories, it will simplify the matching of the power drive line to the power requirements.

PTO SHAFT SAFETY FACTORS INDIRECTLY RELATED

For many years operators of farm machinery have been warned to stop the tractor engine before performing duties off the tractor, such as unplugging the feed mechanism of a machine. It is when this warning is ignored that a hazard exists. One measure, which can be taken to minimize the possibilities of an accident from this cause, is to prevent the machine from plugging in the first place. The operator can control this by not crowding the crop into the machine. The individual manufacturers have taken steps to aid in the prevention of plugging by the following:

The operation of the power take-off shaft of earlier tractors was directly related to the tractor master clutch, which also controlled ground travel. When the tractor was moving forward into the crop with the PTO shaft engaged and the implement feed mechanism became overloaded by the crop, it was necessary for the operator to perform the following acts to release the overcrowding:

1. Depress or release the master clutch which stopped forward travel and rotation of the PTO.
2. Shift the tractor propulsion transmission into neutral.
3. Re-engage the master clutch which now operated the PTO only; thereby relieving the overcrowded condition of the implement feed mechanism.

4. Again depress or release the master clutch.

5. Shift the tractor propulsion transmission back into gear.

6. Engage the master clutch and proceed with normal operation.

It can readily been seen that rather than go through this procedure the operator might gamble on not plugging the machine when it became overcrowded and often he would lose the gamble which would require him to dismount from the tractor to unplug the machine. He might even chose to allow the PTO shaft to continue to run so that the machine could remove the excess crop as he unplugged the feeder. This procedure presented hazardous conditions in areas other than just the PTO.

The first provision to alleviate this condition was the introduction of individual control of ground travel and PTO operation. By being able to stop the forward travel of the tractor and implement, but allowing the PTO to continue to operate, the overloaded condition of the implement could be relieved without completely plugging the mechanism.

Next came the introduction of a rapid means to change ground speed. This allowed the operator to immediately change his forward travel to a slower stepped range by pushing a lever and in so doing he could regulate the amount of material entering the feed mechanism of the implement.

The latest evolution in tractor propulsion is the hydrostatic transmission which permits the operator to control his forward ground travel at an infinitely variable speed ranging from zero miles per hour to the top speed of the tractor; meanwhile his PTO is operating at the fixed proper speed. The speed control of the hydrostatic transmission is a simple easy-to-operate lever which increases the ground speed of the tractor as the lever is advanced forward and reverses the tractor direction when pulled rearward from a neutral position. With this totally variable ground speed control, there is little or no reason for the operator to overcrowd or plug his implement.

CONCLUSION:

The major factor in power take-off shaft accidents involves the entanglement of clothing and resultant effects on the wearer. When presently available shielding, which is provided by the manufacturer is used, the possibility of entanglement is minimized.

A shaft which is unshielded or improperly shielded presents a safety hazard and a continued stress on safety education is required to create an awareness by responsible persons of the impending dangers if the proper guards are not utilized.

A continuing strenuous effort is being made by individual producers of farm machinery and industrial organizations and standardizing bodies to improve shielding and safeguard against its removal. Subjects related to power drive line safety are being studied on a perpetual basis resulting in the adoption of standards which contribute to minimizing potential dangers of associated factors.

At the present time fully shielded drive lines which will comply with ASAE S297T are being developed and tested. These will further enhance the safety of present day shields.

Studies are underway to remove the PTO shaft of the tractor and instead replace it with a splined female member which would not protrude. To couple up to the tractor, the power drive line would plug into the splined female member. When the implement is uncoupled a shielded smooth surface rather than a shaft would exist on the tractor.

The major problem is human education in the use of safety equipment and safe practices.

THE UNIVERSITY OF IOWA
OAKDALE, IOWA 52319

Accident Prevention Laboratory
Institute of Agricultural Medicine
College of Medicine
Oakdale Campus

October 6, 1970

Douglas W. Toms, Director
U.S. Department of Transportation
National Highway Safety Bureau
Washington, D.C. 20591

Dear Mr. Toms:

I have taken considerably longer than I expected to write you concerning our thoughts on submission of a paper describing the farm tractor power take off (PTO) accident situation.

This delay has been due in part to (1) determining if we had any pertinent new information which would, in paper form, update our previous work, and (2) reviewing our data and writings to determine a manner of presentation to best assist you in your determination as visualized from our position here in the Institute.

In review of our latest data (no specific emphasis placed toward uncovering PTO accidents), we can observe little change in the manner in which farm workers are being injured by PTO equipment. It still appears that protrusions on PTO drive lines entangle the worker's clothing, draw him against the revolving shaft and, as his clothing is stripped from his body, traumatize the body seriously and in some instances, cause death. However, it must be understood that we are in no position to extrapolate our data into national figures as we concentrate upon determining injury patterns, incidence or rate data.

Injuries can be found with both new and old equipment. However, there are two problems which will act as a road-block to any dramatic reduction of PTO accidents, even if all new tractors were to come equipped with the most desirable shielding.

1. The average age of the farm tractor, according to statistics

of the Farm Industrial and Equipment Institute (FIEI) is about eleven years, and similarly, there will be found a considerable number of other machines, which are powered by that tractor, of a similar age.

2. The farmer is noted for his innovation and as such, considers make-shift or get-the-job-done practices both practical and expedient. Consequently, such behavior on the part of the farmer, when coupled with the use of aging equipment, will cause accidents.

Since our work on PTO accidents, we have seen a renewed interest in upgrading PTO drive equipment, through the development of new standards of shielding (complete enclosure of the PTO drive line) promulgated by the American Society of Agricultural Engineers (ASAE), assisted by FIEI committees. The development and testing of such equipment by most of the major farm machinery manufacturers and their component suppliers is underway.

This new PTO drive line should dramatically reduce those injuries associated with new equipment. However, because of the older equipment still in use, it will probably be several years before a significant reduction is seen, depending on the replacement and/or junking of the older machinery.

In spite of the best equipment we may provide the farmer, he will still continue to have some accidents due to the nature of his work, the natural elements he must work in, and the fact that as he is both labor and management. However, I am convinced that, if he is provided a safer piece of equipment which will function as well or better than his old equipment, and, if it is durable and appealing, then he will pay the difference for the more desirable item.

Legislation, if promulgated, should probably be limited to new equipment, and if a retro-fit aspect is to be considered, then limit it to that which passes through a machinery dealer's hands for re-sale where proper design and installation can be assured.

It is likely that retro-fit principles will handicap many machines as the PTO Drive line is generally a part of the machine and not the tractor. Thus, if the cost of the new drive line becomes a major portion of the cost of the older machine, then it will not likely be purchased or its shielding will be ignored. This can even be a problem for new machines which are smaller or of limited use (elevators, mowers, etc.) and manufactured by the short-line or small manufacturer. However, the application of the new ASAE standards of shielding should not present the same total production sale-cost relationship to manufacture even though the ultimate cost must be paid for by the buyer.

I believe the new shields presently developed and nearing manufacture by the industry will perform the functional requirements as summarized in the attached Institute Bulletins which are still, in our opinion, the best description of the PTO accident problem.

I hope the foregoing will be of assistance to you in your deliberations.

Yours truly,

L W Knapp Jr

L. W. Knapp, Jr., Chief
Accident Prevention Section

INSTITUTE OF AGRICULTURAL MEDICINE

LWK/kch

Enclosures: Bulletin #10, "An Epidemiological Study of Power Take-Off Accidents"
Bulletin #11, "The Farm Tractor: Overturn and Power Take-Off Accident Problem"

NOTE: (ADDED BY THE NATIONAL HIGHWAY SAFETY BUREAU)
Enclosures to this letter are not reproduced in this report. However, they appear in References at the end of the report.

THE VOLUNTARY STANDARDS PROGRAM
FOR
AGRICULTURAL TRACTORS

Prepared For Submission
On Behalf Of

The Farm And Industrial Equipment Institute

In Response To A Request
From

U.S. Department Of Transportation
National Highway Safety Bureau

By

L. H. Hodges

The Voluntary Standards Program
for
Agricultural Tractors
by
L. H. Hodges

The Farm and Industrial Equipment Institute (FIEI) has long recognized the value of reasonable standards. In 1927, the FIEI Engineering Committee developed its first industry standard. It provided for the shielding of the agricultural tractor power take-off (PTO) and a standard PTO shaft and drawbar to permit interchangeability between all makes of agricultural tractors and PTO driven machinery. This standard provided for operator safety as well as allowed for the attaching of PTO machinery made by all large and small manufacturers to attach to the tractor without special hitch kits.

The PTO standard was subsequently submitted to the Society of Automotive Engineers (SAE) for their consideration as a technical society standard. In 1950, the American Society of Agricultural Engineers (ASAE) undertook an expanded program for agricultural standards. The FIEI PTO standard was submitted to them for consideration as an ASAE standard. Generally speaking, SAE concentrates on standards for agricultural tractors whereas ASAE concentrates on standards for agricultural machinery. In many cases, one standard will involve both tractor and implements. For this reason, most standards involving agricultural tractors and agricultural machinery are published by both societies. Except for minor changes in wording, the standards published by both societies are identical.

The FIEI Engineering group of committees function on behalf of the Industry Trade Association on all matters dealing with Standards and related Engineering matters. As the FIEI Engineering Committees are currently operating, they do not develop standards but develop proposals that are submitted to either or both SAE and ASAE for their consideration as standards. Because the FIEI Engineering Committees include the industry expertise and the people with the greatest interest in farm machinery safety, they have developed proposals for all of the standards published by the SAE and ASAE involving safety for agricultural tractors and agricultural machinery. Because of the excellent proposals developed by the FIEI, both SAE and ASAE look upon the FIEI as the source for reasonable safety standards for tractors.

This paper was prepared for submission to the DOT at their request on behalf of FIEI. The author is Director of Research and Technical Services for the J I CASE COMPANY, RACINE, WISCONSIN, and is presently serving on the Safety Policy and Engineering Policy Committees of the Institute. He is also Chairman of ANSI Committee B-114, Agricultural Tractors and Agricultural Machinery and is past Chairman of two important ASAE Committees actively engaged in the development of Standards; i.e., the ASAE Divisional Standards Committee (PM-03) of the Power and Machinery Division, and the Society's Committee on Standards (T-1).

Subcommittees are organized under the Engineering Committee to develop proposals on specific items. All firms with an interest in the particular subject and are able to supply expertise are encouraged to participate in the development of specific proposals. Final approval for any proposal must come from the FIEI Engineering Policy Committee prior to submission to SAE and ASAE.

The FIEI Engineering Policy Committee also participates in International Standards Organization (ISO) through the American National Standards Institute (ANSI). Two SAE-ASAE standards have been adopted by ISO with modifications, as international standards. The two standards are the SAE-ASAE PTO standard and the Three Point Hitch standard. These standards are used on most agricultural tractors manufactured the world over.

Exhibit I is a pictorial and graphic portrayal of the flow of voluntary standard proposals as they progress from the start of industry participation through the professional societies and ANSI to ISO for consideration as a world standard.

This exhibit also depicts the interrelationships between trade associations, professional societies, ANSI, and ISO in the voluntary standardization process as it currently applies, and is being practiced in the agricultural tractor industry.

FIEI is a staunch supporter and active participant in the voluntary standardization process at all levels, and especially those of ANSI Committee B-114. FIEI has provided the driving force behind the U.S. participation in the ISO activity relating to agricultural tractors, and must be credited with the success in obtaining recognition by this important world body of the two U.S. Standards.

To expand further on the subject of voluntary standards, please refer to Exhibit II which lists the individuals and their affiliation who make up the committees having responsibilities for agricultural tractor standards in the FIEI, SAE, ASAE, and ANSI. It will be noted that quite a variety of occupational specialties are included in the people representing the many organizations that are involved in the development and adoption processes of the voluntary standards for agricultural tractors and agricultural machinery.

There currently are published at least 35 industry standards which relate directly or indirectly to safety for agricultural tractors. In many cases, the standards will involve other items of standardization but will include the necessary safety requirements for the particular item. In many cases the standards specify testing procedures and performance requirements but in other cases, design specifications are included as interchangeability is involved. The names and numbers of various industry standards which relate directly or indirectly to safety and their respective publication dates are shown in Exhibit III.

It will be noted that these standards were developed over a period of many years. The proposal for at least 21 of these standards was originated directly by FIEI whenever the members of the FIEI Engineering Policy Committee determined that a standard would be useful and promote the interest of safety. Statistical information when available serves as a guide in establishing priorities for the development of proposals for safety standards.

The full text of these various standards are not included as (exhibits), as they are readily available from the respective professional societies.

Since the texts of these standards are not enclosed here it seems highly desirable to comment in general terms on several of the important agricultural tractor safety standards which are listed in Exhibit III:

1. Safety for Agricultural Equipment - ASAE R318.

   - A systems document listing the essential elements to improve the degree of personal safety for those involved during the normal operation and servicing of such equipment.

2. Operator Controls on Agricultural Equipment - ASAE R335.

   - Establishes uniformity of location and direction of motion of those controls located at the operator's normal position.

3. Universal Symbols for Operator Controls on Agricultural Equipment - ASAE R304.

   - Provides a symbolic language for operator controls on this type of tractors and equipment.

4. Lighting and Marking of Agricultural Equipment on Highways - ASAE S279.

   - A systems document to provide specifications for lighting and marking when such equipment is operated or traveling on a highway. It includes the lights, reflectors, flashing warning lights, the Slow Moving Vehicle Identification Emblem (SMV), and other essential elements of the system.

   This standard has been accepted by the National Committee on Uniform Traffic Laws and Ordinances for inclusion in the Uniform Vehicle Code. A separate standard provides the specifications for, a self-powered warning light for any such equipment not manufactured with an electrical system.

5. Operator Protection for Wheel-Type Agricultural Tractors - ASAE S305.

   - Establishes requirements for the protection of operators of this equipment to minimize the possibility of operator injury resulting from accidental upsets during normal operations. It includes such essential elements as --

     -- a protective frame or structure
     -- seat belts
     -- seat mountings
     -- spill-proof caps for batteries, fuel tanks, oil reservoirs, coolant systems, etc.

The design requirements and test procedures for the various "hardware" items in the system are covered in separate standards for these types of protective systems for agricultural tractors --

- Protective Frame - ASAE S306.
- Protective Frame with Overhead Protection - ASAE S310.
- Protective Enclosure (Cabs) - ASAE S336.

Generally, standards are considered to represent the minimum requirements. The standards involving agricultural tractors and agricultural machinery are not considered minimum standards by the industry for they specify practicable, reasonable, and effective safety requirements.

The acceptance and use of the SAE-ASAE standards has been most gratifying, even though their use is voluntary. With the high current interest in safety, maximum acceptance is anticipated.

Looking to the future it is encouraging to note that three new proposals involving safety are currently in the process of development by the FIEI Engineering Committee. They are as follows:

- Safety frames for forestry tractors.
- Testing procedure and performance requirements for agricultural tractors.
- Safety chains for towed agricultural machinery.

The standards effort within FIEI has now expanded from its beginning in the late 1920's to its present level of 24 working committees functioning under the guidance of the Engineering Policy Committee. A complete listing of the names of these committees is included in Exhibit IV. Their name is usually descriptive of the specialized scope and purpose of the committee. It should be noted that 7 of the 24 working committees are directly concerned with operator protective systems or devices and safety, and one committee concerns itself with the all important subjects of noise and operator environment.

In addition to the three new areas of standardization activity listed previously, the FIEI has a concern for noise and the possible effects from over-exposure to noise levels that are too high. This concern is exemplified by the financial support for the SAE Research Project R-4, "A Study of Noise Induced Hearing Damage Risk for Operators of Farm and Construction Equipment" conducted by Southwest Research Institute. The list of financial sponsors for this study include the following:

Department of Transportation
Construction Industry Manufacturers Association
Farm and Industrial Equipment Institute
Power Saw Manufacturers Association
Society of Automotive Engineers

This study generally concluded that the nature of the noise and the exposure patterns for the operator of farm and construction machinery are different from those experienced by the factory worker and that more research is needed for the compilation of data to support meaningful standards in this area.

While this research is being conducted, the various companies in the industry have major engineering programs to effectively control and reduce the noise levels to which the operator is subjected. Effective results of this engineering effort can be found in the new cabs now being offered in conformance to the ASAE protective enclosures standards. The results of these efforts will likely precipitate the development of ASAE-SAE design and test standards for noise control in much the same manner as the operator protective system standards.

Due to the nature of the accident trauma involving agricultural tractors and agricultural machinery, the main thrust of the voluntary standards effort has been directed towards the systems approach and toward injury reduction.

The Industry's 47 years of experience as a staunch supporter of, and active participant in the voluntary standards program and the resultant U.S. safety standards for agricultural tractors, coupled with our manufacturing and marketing experience in the major tractor market throughout the world has led to the conclusion that the present U.S. system has at least two distinct advantages over any other system. First, it responds effectively and promptly to changes in technology and an advance in the state-of-the-art; and, secondly, it encourages those innovations which bring about such advances.

The title and the main thrust of this paper is in regard to the voluntary standards program and current safety standards for agricutural tractors, but the Department of Transportation's request included a reference to the additional subjects of retrofit and the economic impact.

One cannot deal intelligently with a retrofit question without defining what devices, systems, or standards are to be considered. There are no specific standards which address themselves directly to the retrofit question. In the event this subject is to be given a detailed study, it is conceivable that the same group of experts and the same administrative procedures that develop the present standards applicable to agricultural tractors could be employed to perform such an in depth study.

The complexity of the retrofit question can perhaps be placed in a reasonable perspective if we deal with the subjects of lighting and marking per ASAE S279, the protective frame system per ASAE S306, and a protective enclosure per ASAE S336.

If the particular tractor being considered for retrofit was originally produced with an electrical system, the technical complexities of adding the lighting and marking devices specified in S279 which includes the SMV emblem, would not be considered great nor insurmountable. The economic impact of such addition would be in the list price range of $50 to $75 per tractor.

The technical complexities multiply rapidly when moving from the subject of lighting and marking, to protective frames per ASAE S306. In some instances the protective frames being provided for current tractor models could not be fitted directly to prior models as a result of dimensional differences. In other instances the strength of the tractor component(s) to which the protective frame could be attached might be inadequate. Seat belt mountings, and the application of spill proof caps add another dimension to the technical complexity. Information gained during the extensive testing which was performed by the various companies during the development of protective frames for current tractor models has led some of the engineers knowledgeable in this area to express the judgment that the indiscriminate application of protective frames to some of the older model tractors could create some new and additional operator hazards against which the system may afford little or no protection unless verified by extensive testing.

The economic impact of the application of the protective frame system will vary considerably from the small tractor to the large tractor. Such applications have been estimated to be in the list price range of $195 for the smaller units, and up to $450 for some of the larger tractors.

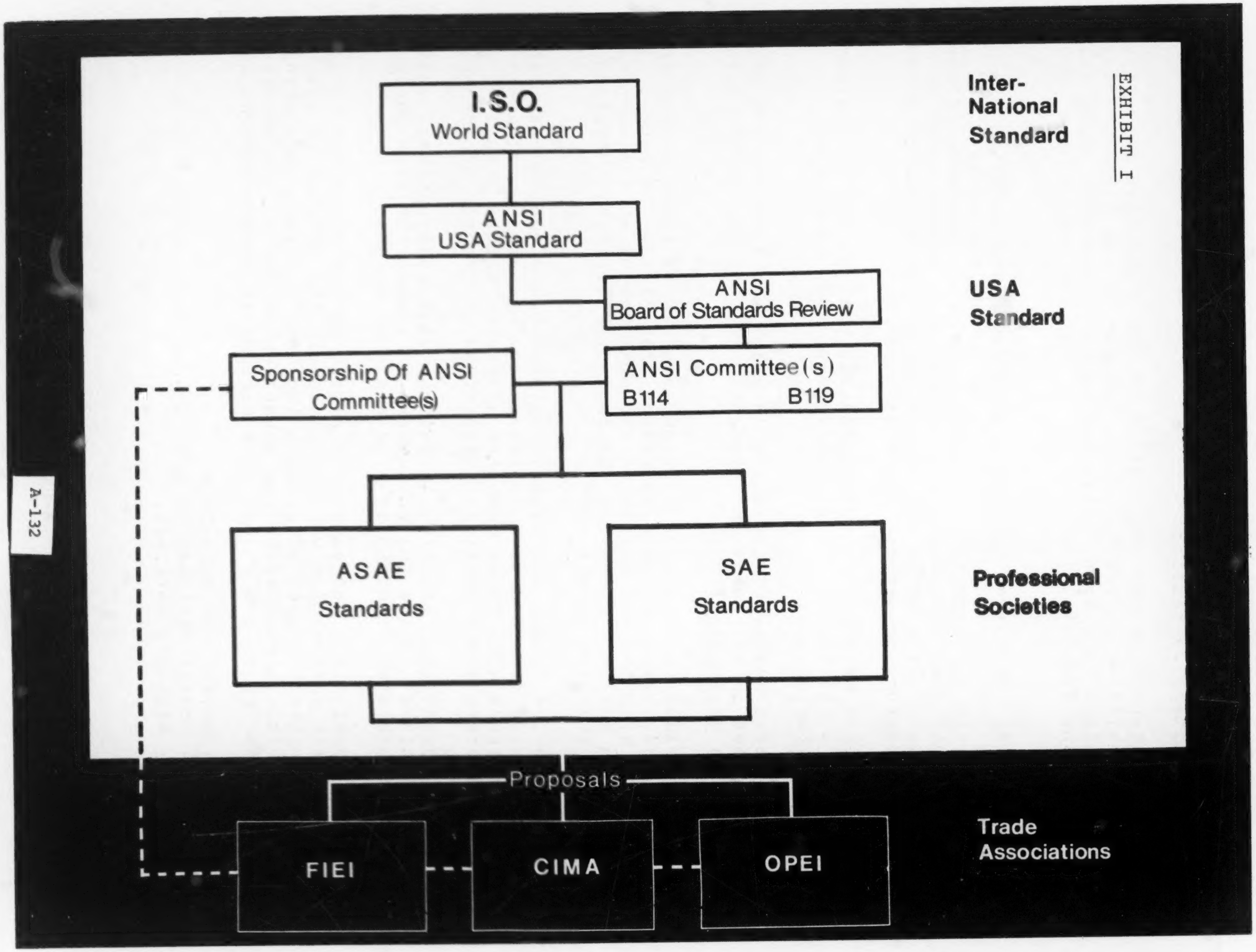
It is generally considered economically unsound and technically unfeasible to consider the application of a complete protective enclosure system per ASAE S336 to older models of tractors. Since these new protective enclosures are offered with a wide range of accessories their list price may easily range from $1,200 to some $2,200 per tractor, or perhaps somewhat more.

A careful review of the voluntary standards program for agricultural tractors and a measure of its effectiveness leads us to these significant conclusions:

- The total number of accidents in which the farm tractor is involved is not large in comparison to numerous other types, and is decreasing.
- The voluntary standards program seems to be working well in our industry. It has accelerated dramatically in recent years with the net result of the most stringent and complete design and test standards for roll-over protective systems found anywhere in the world.
- Protective frames and especially protective enclosures (cabs) now being provided in ever-increasing numbers in voluntary compliance with these industry standards should greatly accelerate the present downward trend in tractor accidents.
- The educational efforts, in harmony with other phases, must be employed to the fullest extent to remove the high incident rate operator from the tractor accident scene.
- The compilation and careful analysis of new and better tractor accident information which can measure the results of the industries diligent efforts in the last several years should be seriously studied before embarking on new or ill conceived programs which could lead to a serious imbalance between --

  -- Scientific Relevance
  -- Social Pertinence, and
  -- Economic Interest.

EXHIBIT I


I.S.O.
World Standard
ANSI
USA Standard
ANSI
Board of Standards Review
Sponsorship Of ANSI Committee(s)
ANSI Committee(s)
B114
B119
ASAE Standards
SAE Standards
Proposals
FIEI
CIMA
OPEI
Inter-National Standard
USA Standard
Professional Societies
Trade Associations

AGRICULTURAL TRACTOR STANDARDIZATION COMMITTEES AND MEMBERSHIPS AS OF THE YEAR 1970

EXHIBIT II

FIEI ENGINEERING POLICY COMMITTEE

Chairman - J.H. Zich, Ford Motor Company, Birmingham, MI

A.W. Acker, Henry Mfg. Co., Topeka, KS
R.A. Adee, Hesston Corp., Hesston, KS
E.M. Brumbaugh, J I Case Co., Racine, WI
C.L. Callum, Allis-Chalmers, Milwaukee, WI
W.M. Davis, John Deere Tr. Wks., Waterloo, IA
R.M. Doll, Massey-Ferguson Inc., Detroit, MI
R.L. Erwin, Ford Motor Co., Birmingham, MI
R.G. Ferris, Starline, Inc., Harvard, IL
M.E. Hart, Allis-Chalmers, Milwaukee, WI
L.H. Hodges, J I Case Co., Racine, WI
K.E. Hohnl, J I Case Co., Racine, WI
S. Liedtke, John Deere Tr. Wks., Dubuque, IA
W. McDougall, Avco New Idea, Coldwater, OH
D.H. McNeil, Cockshutt Farm Equip., Brantford, Ontario, CA
W.G. Moore, Lilliston Corp., Albany, GA
R.E. Prunty, White Farm Equip., Charles City, IA
E.L. Scheidenhelm, Hart Carter Co., Mendota, IL
L.H. Skromme, Sperry Rand Corp., New Holland, PA
R.B. Skromme, Massey-Ferguson Inc., Detroit, MI
J.W. Stocking, Pittsburg Forgings Co., Coraopolis, PA
G.R. Sutherland, John Deere, Des Moines, IA
W.E. Witt, Fox Tr. Div. Koehring Co., Appleton, WI
J.F. Ziskal, IHC Farm Equip., Res. & Eng., Hinsdale, IL

SAE TRACTOR TECHNICAL COMMITTEE

Sponsor - F.C. Walters, John Deere Waterloo Tr. Wks., Waterloo, IA
Chairman - W.J. Foxwell, Ford Motor Co., Birmingham, MI

D.G. Bamford, Massey-Ferguson, Detroit, MI
E.M. Brumbaugh, J I Case Co., Racine, WI
R. Candee, John Deere Tr. Wks., Waterloo, IA
R.N. Coleman, IHC, Hinsdale, IL
W.S. Coleman, Minneapolis-Moline, Hopkins, MN
W.R. Dalenberg, IHC, Hinsdale, IL
H.K. Dommel, Oliver Corp., Charles City, IA
S.C. Heth, Jacobsen Mfg. Co., Racine, WI
R.W. Johansen, Allis-Chalmers, West Allis, WI
J.B. Liljedahl, Purdue U., Lafayette, IN
M.R. North, J I Case Co., Racine, WI
C.T. O'Harrow, Ford Motor Co., Birmingham, MI
R.J. Ronayne, Oliver Corp., Charles City, IA
N.A. Sauter, Deere & Co., Moline, IL
L. Williams, John Deere Tr. Wks., Waterloo, IA
E.J. Zeglen, Massey-Ferguson, MI
J.H. Zich, Ford Motor Co., Birmingham, MI
J.C. Crawford, SAE Staff, New York, NY

ASAE POWER & MACHINERY TECHNICAL COMMITTEE (PM-03)

Chairman - G.P. Barrington, U. of Wisconsin, Madison, WI
Vice Chairman - J.F. Ziskal, IHC, Hinsdale, IL

E.M. Brumbaugh - J I Case Co., Racine, WI
W.R. Dalenberg, IHC, Hinsdale IL
W.M. Davis, John Deere Tr. Wks., Waterloo, IA
H.K. Dommel, White Farm Equip., Charles City, IA
Thomas Evans, J I Case Co., Bettendorf, IA
F.P. Hanson, 121 W Detweiller Dr., Peoria, IL
R.P. Harbage, AVCO, Coldwater, OH
S.C. Heth, Jacobsen Mfg. Co., Racine, WI
R.W. Johansen, Allis-Chalmers, West Allis, WI
L.W. Larson, USDA, Beltsville, MD
R.H. Lytle, Minneapolis-Moline, Hopkins, MN
C.T. O'Harrow, Ford Tr. Oprns., Bloomfield Hls, MI
W.L. Scott, Massey-Ferguson, Toronto, Ont. CA
A.B. Skromme, John Deere, E.Moline, IL
R.B. Skromme, Massey-Ferguson, Detroit, MI
E.W. Tanquary, Retired, Elmhurst, IL
M.E. Walberg, Allis-Chalmers, Waukesha, WI
R.E. Wallin, Sperry Rand Corp., New Holland, PA
J.A. Weber, U. of Illinois, Urbana, IL
J.H. Zich, Ford Motor Co., Birmingham, MI

AMERICAN NATIONAL STANDARDS COMMITTEE B114
AGRICULTURAL TRACTORS AND AGRICULTURAL MACHINERY

Chairman - L.H. Hodges, J I Case Co., Racine, WI
Vice Chairman - M. Hansen, John Deere Waterloo Tr. Wks., Waterloo, IA

G. Barrington, ASAE, Madison, WI
K.A. Chidley, 777 N. Hicks Rd., Palatine, IL
J.C. Crawford, SAE, New York, NY
C. de St. Paer, Am. Farm Bureau Fed., Wheaton, IL
W.J. Foxwell, Ford Trac. Op., Birmingham, MI
R.H. Hahn, ASAE, St. Joseph, MI
R.E. Heston, Grinnell Mutual Reins. Co., Grinnell, IA
R. Konen, R. 1, Aurora, IL
W.B. Knorst, FIEI, Chicago, IL
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S.W. Taylor, ANSI, New York, NY
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14 September 1970

EXHIBIT III

AGRICULTURAL TRACTOR SAFETY ORIENTED STANDARDS

ASAE Standard	SAE Standard	Title	ASAE Publication Date	Safety Orientation
S201	J716	Application of Hydraulic Remote Control Cylinders to Agricultural Tractors and Trailing-Type Agricultural Implements	1949	Hitching Safety
S203	J718	540-RPM Power Take-Off for Agricultural Tractors	1927	Power Take-Off Safety
S204	J719	1000-RPM Power Take-Off for Agricultural Tractors	1958	Power Take-Off Safety
R207	J721	Operating Requirements for Power Take-Off Drives	1953	Power Take-Off Safety
R208	-	Definition of Reportable Accident	1959	General Safety
S210	J720	Tractor Belt Speed and Pulley Width	1944	Operator Safety
S214	J723	Safety Lighting Breakaway Connector for Farm Implements	1957	Highway Safety
S215	J724	Safety Lighting Breakaway Connector Cable for Farm Implements	1957	Highway Safety
S216	-	Self-Powered Electric Warning Lights	1961	Highway Safety
S217	J715	Three-Point Free-Link Attachment for Hitching Implements to Agricultural Wheel Tractors	1959	Hitching. Safety
R219	J712	Agricultural Tractor and Equipment Disk Wheels	1952	Highway Safety
R232	-	Lubrication Chart and Diagram for Tractors and Agricultural Machinery		General Safety

ASAE Standard	SAE Standard	Title	ASAE Publication Date	Safety Orientation
S276	J943	Slow-Moving Vehicle Identification Emblem	1964	Highway Safety
S277	J725	Mounting Brackets and Socket for Agricultural and Industrial Equipment Warning Lamp and Slow-Moving Vehicle (SMV) Identification Emblem	1964	Highway Safety
S278	J909	Attachment of Implements to Agricultural Wheel Tractors Equipped with Quick-Attaching Coupler for Three-Point Free-Link Hitch	1964	Hitching Safety
S279	J908	Lighting and Marking of Agricultural Equipment and Industrial Equipment on Highways	1964	Highway Safety
S295	J709	Agricultural Tractor Tire Loading and Inflation Pressures	1965	Highway Safety
S297T	J955	Full Shielding of Power Drive Lines for Agricultural Implements and Tractors	1966	Power Take-Off Safety
R304	J389	Universal Symbols for Operator Controls on Agricultural and Industrial Equipment	1967	Operator Safety
S305	J333	Operator Protection for Wheel Type Agricultural and Industrial Tractors	1967	Operator Safety
S306	J334	Protective Frame Test Procedures and Performance Requirements	1967	Operator Safety
S307	J974	Flashing Warning Lamp for Remote Mounting on Agricultural and Industrial Equipment	1967	Highway Safety
S310	-	Protective Frame with Overhead Protection - Test Procedures and Performance Requirements	1968	Operator Safety
S316T	-	Application of Remote Hydraulic Motors to Agricultural Tractors and Trailing-Type Agricultural Implements	1968	Hitching Safety

ASAE Standard	SAE Standard	Title	ASAE Publication Date	Safety Orientation
*R318	-	Safety for Agricultural Equipment and Industrial Wheeled Equipment	1968	Operator Safety
R331T	-	Implement Power Take-Off Drive Lines	1969	Power Take-Off Safety
**R333	-	Agricultural Tractor and Industrial Tractor Auxiliary Power Take-Off Drives	1969	Power Take-Off Safety
***R335	-	Operator Controls on Agricultural Equipment and Industrial Equipment	1969	Operator Safety
S336	-	Protective Enclosures - Test Procedures and Performance Requirements	1970	Operator Safety
			SAE Publication Date	
-	J4	Motor Vehicle Seat Belt Assemblies	1955	Operator Safety
-	J585	Tail Lamps	1918	Highway Safety
-	J594	Reflex Reflectors	1931	Highway Safety
-	J787	Motor Vehicle Seat Belt Anchorage	1961	Operator Safety
-	J975	Headlamps for Farm and Light Industrial Equipment	1967	Highway Safety
-	J976	Combination Tail and Floodlamp for Farm and Light Industrial Equipment	1967	Highway Safety

*R318 - Supersedes ASAE 275 Improving Safety on Farm Implements adopted 1964, and ASAE R280 Improving Safety on Farm Tractors adopted 1964.

**R333 - Supersedes ASAE R206 Farm Tractor Auxiliary Power Take-Off Drives, corresponds with SAE J717, and adopted by ASAE in 1955; and ASAE R311 Mid Power Take-Off for Farm and Light Industrial Tractors adopted 1968.

***R335 Supersedes R234 Operator Controls on Farm Tractors, corresponds to SAE J841, adopted by ASAE in 1962; and ASAE R235 Operator Controls on Self-Propelled Implements adopted 1962.

EXHIBIT IV

FARM & INDUSTRIAL EQUIPMENT INSTITUTE (FIEI) ENGINEERING COMMITTEES

1. Engineering Policy Committee
    - Ad Hoc - Safety Chains
    - Ad Hoc - Tractor & Trailer Braking
2. Agricultural Fasteners Committee
3. Agricultural Hydraulics Committee
4. Safety Committee Agricultural Section
5. Baler-Twine & Wire Committee
6. Fertilizer and Chemical Committee
7. Forestry
8. Industrial Hydraulics Committee
9. Industrial Loaders & Backhoe Committee
10. Industrial Safety Committee
11. Industrial Special Equipment Committee
12. Industrial Tractors Committee
13. ISO - Disc Committee
14. ISO - Mower - Combine Cutter Bar Committee
15. ISO - Sprayer Committee
16. Lighting of Tractors and Implements Committee
17. OECD Combine Test Code Committee
18. OECD Small Tractor Test Code Committee
19. Power Take-Off Committee
20. T-Hook Committee
21. Three-Point Hitch Committee
22. ANSI-ISO
23. Noise and Pollution Committee

IMPROVING SAFETY OF AGRICULTURAL TRACTORS

by a Special Task Group of

The American Society of Agricultural Engineers

American Society of Agricultural Engineers
St. Joseph, Michigan 49085

This paper was prepared specifically for the National Highway Safety Bureau of the U. S. Department of Transportation, as invited by Douglas W. Toms, Director, 19 August 1970. Mr. Toms solicited it for the Department of Transportation's study of agricultural tractor accidents, deaths, and injuries as directed by the Congress of the United States.

September 25, 1970

IMPROVING SAFETY OF AGRICULTURAL TRACTORS

Prepared by the following special task group:

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NOTE: (ADDED BY THE NATIONAL HIGHWAY SAFETY BUREAU)

Appendices V, VI, VII, and VIII, submitted with the paper from the American Society of Agricultural Engineers are not reproduced in this report.

APPENDED REFERENCES

Appendix	Title
I	ASAE Committees
II	ASAE Safety Goals and Plans
III	The ASAE Cooperative Standards Program
IV	ASAE Standards and Recommendations with Safety Provisions for Tractors and Implements
V	Standardization in The American Society of Agricultural Engineers
VI	Cooperative Activities with Other Organizations
VII	Standards - A Vital Tool in Engineered Agriculture
VIII	Letter of 19 August 1970 from Mr. Douglas W. Toms, Director of National Highway Safety Bureau, U. S. Department of Transportation
IX	ASAE Technical Papers Pertaining to Agricultural Tractor Safety - 1960-1970

September 25, 1970

IMPROVING SAFETY OF AGRICULTURAL TRACTORS

Introduction

In August 1970, the National Highway Safety Bureau of the U. S. Department of Transportation (DOT) advised the American Society of Agricultural Engineers (ASAE) that a study was being made of agricultural tractor accidents, deaths and injuries for a report to Congress. As a part of their study, the National Highway Safety Bureau of DOT invited ASAE to prepare a paper to include the following points:

A. ASAE Standards that affect agricultural tractors and the organizations involved in the ASAE standard setting process.

B. Whether federal agricultural tractor safety standards are required, and if so, in what areas they should be prepared, by whom, in what order of priority, and how they should be enforced.

C. How the retrofit problem should be handled.

This paper is presented in response to that request. The ASAE has an active agricultural safety program, and is pleased with the opportunity to help the DOT consider how to improve agricultural tractor safety as directed by Congress.

To appreciate ASAE's response to the above invitation, it is important to have some understanding of ASAE's membership, its objectives, and how its resources are applied to society's needs and problems. The early portions of this paper will provide that information, and then the points listed above will be addressed.

What is the American Society of Agricultural Engineers?

ASAE is a nonprofit, technical, and educational organization working primarily for the interchange of information on engineering in agriculture. It was founded in 1907 and has over 6300 members in the United States, Canada and 74 other countries.

Membership is open to anyone who has an active interest in engineering in agriculture. Members indicate interests in five ASAE divisions: Power and Machinery; Soil and Water; Electric Power and Processing; Structures and Environment; Food Engineering. ASAE has no company memberships--only personal memberships.

ASAE's objects are to promote the science and art of engineering in agriculture; to encourage original research; to foster agricultural engineering education; to advance the standards of agricultural engineering; to increase and extend the association of agricultural engineers among themselves and with allied scientists and technologists; to encourage the professional improvement of its members; and severally and in cooperation with other groups, to broaden the usefulness of agricultural engineering.

About 20 percent of the ASAE members are researchers and educators in colleges and universities; 20 percent are employed by the federal government, including researchers and extension specialists; and approximately 60 percent are industry employees, consultants, and other self-employed persons.

How ASAE functions

ASAE's primary activities include technical publications, standards and recommendations, meetings and conferences, and committee activities.

ASAE conducts two national meetings each year, in addition to the many meetings of its 10 regions, 37 sections, and 4 chapters. ASAE's contributions are generated primarily through its 170 committees. (See Appendix I) Eighty of the committees have standards-producing experiences or capabilities.

Safety Committee

The Agricultural Safety Committee (T-2) is responsible for organizing and administering safety activities through ASAE's scope of interests. This committee, organized in 1941, is responsible directly to the ASAE Technical Council of the Board of Directors. In December, 1969, the committee began developing a plan which has as its objective 50 percent reduction of fatal farm accidents by 1980 as well as reduction of non-fatal farm accidents. (See Appendix II)

Cooperative Standards Program

The most active and far-reaching ASAE activity that improves agricultural safety is the Cooperative Standards Program. (See Appendix III) This voluntary activity provides the organizational machinery through which individuals and organizations work to develop ASAE Standards and Recommendations. (For this discussion, the term standards will be used as reference to recommendations and standards since both types of documents are similar in purpose.)

ASAE standardization activities include cooperative projects with other organizations such as the Society of Automotive Engineers, American Society for Testing and Materials, National Safety Council, American National Standards Institute, and others. Committees of the Farm and Industrial Equipment Institute make major contributions in applying the facilities and talents of industry to research and evaluate the feasibility of many proposals that are submitted for consideration as ASAE agricultural machinery standards.

Public service participation

Through the membership, meetings, and committees of ASAE and its cooperative standardization efforts, there is a unique opportunity for participation by public service engineers such as those employed by the federal government and universities. For instance, the Power and Machinery Division Standards Committee, which coordinates and approves development of all standards for agricultural tractors and implements, includes several public service members in accordance with committee bylaws. Members include land-grant university professors, USDA engineers, and farmers in addition to engineers employed by industry. Although standards are intended primarily to guide industry, public service members participate in the development or review of every standard at three or more levels in the ASAE standardization procedures.

Standards activities are not new to ASAE. The first standards committee was formed in 1910, three years after ASAE was founded. The first ASAE Standard was published in 1912. ASAE standards activities have grown steadily since that time with major growth in the last 20 years. In 1954, the Society published 20 standards. The 1970 AGRICULTURAL ENGINEERS YEARBOOK includes 120 standards. Twenty-eight of these documents include provisions for safety of agricultural tractors and other machines.

Tractor safety standards

There are now 22 ASAE Standards with provisions for agricultural tractor safety on these and other subjects:

Overturn protection for tractor operators
Power take-off drives and shielding
Lighting and marking for the highway
Slow-moving vehicle emblem for the highway
Tires
Three-point hitches and couplers
Operator controls
Operator control symbols
General safety: shielding, operator station safety, fire safety, warning instructions.

In addition, standards are being developed on these subjects concerned with tractor safety:

Safety chains (auxiliary safety couplings)
Brake performance and testing procedures
Tractor loader stability
Operator protection for forestry tractors.

(See Appendix IV for a complete listing of ASAE Standards and Recommendations with provisions for agricultural machinery safety.)

ASAE standardization procedures

Any ASAE member, ASAE committee, nonmember, or organization outside ASAE may propose standards or express the need for the development of standards by ASAE. Standards are developed by ASAE committees, by other organizations, or in cooperative efforts between ASAE and other groups. The policies and procedures are prescribed in the "ASAE Standardization Guide" (available on request), and summarized in "Standardization in the American Society of Agricultural Engineers." (See Appendix V) Regardless of its source, a proposed standard is submitted to the Standards Committee of one or more of the five technical divisions for review or further development. It is then balloted before being submitted to two higher levels of review before approval for publication.

ASAE has international influence in standardization through its membership in the American National Standards Institute and through contacts with standards setting organizations abroad such as the International Organization for Standardization (ISO), and the Organization for Economic Cooperation and Development (OECD Europe). Several ASAE Standards have been the basis for United States contributions to international farm equipment standards through ISO.

The principle of voluntary standards and self-regulation has contributed greatly to the productivity and present standard of living in our country. Because of its effectiveness this principle is heartily endorsed by ASAE. All standardization documents published by the Society are informational and advisory only. Their use is entirely voluntary, and there is no agreement to adhere to any of them. Yet, ASAE Standards and especially those concerned with tractor safety, enjoy a high degree of recognition and prompt compliance.

An example of cooperative standards effectiveness

The history of ASAE Standard S276, Slow-Moving Vehicle Identification Emblem (SMV) will demonstrate: 1) Cooperation of several groups in recognizing a need and developing a solution through standards; 2) Promptness and extent of compliance with standards; 3) Standards as a basis for codes and regulations.

Cooperation. About ten years ago, the department of agricultural engineering at The Ohio State University initiated research to develop a unique symbol to identify farm machines as vehicles that move much slower than cars on the highway. Such identification was considered necessary to reduce the frequency of rear-end collisions between automobiles and farm machines. The research was funded by the Automotive Safety Foundation. Through cooperative efforts with the National Safety Council, the Farm and Industrial Equipment Institute, and others, ASAE developed and published the standard that was based on land-grant university research, funded by another research organization, and adopted by an affected industry.

Compliance. After ASAE S276, which defines the SMV emblem, was adopted in 1964, the emblem was promptly provided by many farm equipment manufacturers and farm suppliers. Its use was, and still is, widely promoted by the National Safety Council, insurance companies, and farm organizations. Michigan statistics show a significant reduction in slow-moving vehicle accidents since their regulations required the SMV emblem.

Basis for regulations. Engineering standards can provide a basis for regulations. The SMV emblem has been included in highway legislation in 26 states and 5 Canadian provinces. Legislation is pending in several others. The SMV emblem has been incorporated into the Uniform Vehicle Code as a guide to all states. The current issue of the standard, ASAE S276.2, has been submitted to ANSI for consideration as a national standard, and should eventually become a worldwide highway safety symbol. All this came about through voluntary standards activities.

Voluntary standardization has worked because it provides for affected persons to participate in setting reasonable performance goals based on technical and practical experience; because it sets desired levels of performance, yet allows for individuals and manufacturers to exceed the desired levels without unnecessarily restricting initiative and creativity; and because it is flexible and able to respond quickly to needs and to changing technology for improved levels of safety performance.

Should we have federal standards to improve agricultural tractor safety?

Among the 6300 ASAE members there are varied opinions on this question. This task group believes ASAE should not, formulate or promote a position on questions of this type. As described previously, ASAE has long recognized the need to improve agricultural tractor safety and continues to work toward reducing agricultural tractor accidents. If Congress determines that federal regulations are necessary in some areas, it is recommended that they be based upon the technology and expertise from which ASAE Standards are derived. ASAE and other organizations with similar concerns and capabilities can provide a ready resource of talent to define technically and economically feasible and practicable performance standards.

ASAE experience with safety-related standards indicates that they are most effective when they are reasonable, not only for the manufacturer, but especially for the user. Persons who participate in developing ASAE Standards are generally sensitive to the needs and habits of the user - in this instance, the farmer. Such sensitivity is essential whether developing voluntary performance standards or federal regulations.

Areas and priorities for developing regulations or standards

ASAE safety-related standards are now published for areas of apparent greatest need: Power take-off shielding; lighting and marking of agricultural machines for highway travel; overturn protection in case of tractor upset, to name a few. The priorities for developing these and other ASAE Standards were based on the limited available statistics, and on the concern and judgment of persons working through the ASAE technical meetings and standardization programs. (See Appendix IV)

ASAE Standards have contributed significantly to safety by providing a basis for uniformity among the states in situations that affect the public. The standard on lighting and marking on the highway, ASAE S279.4, which was the basis for Section 12-215 of the 1968 Uniform Vehicle Code, is an example. Other similar opportunities to provide uniformity in the public interest appear to warrant early emphasis as evidenced by current ASAE standards projects on brakes and safety chains.

Specific mechanisms alone will not prevent all accidents. It is also necessary to consider operators and their environments. Educating or training machine operators could improve personal safety. Effective education or training should be based on accident analysis, human factors, and human behavior in agricultural situations. Technical and professional organizations offer a source of judgment and expertise that can be utilized in developing education and training programs.

Need for accident information. As ASAE committees attempt to establish priorities, they repeatedly note a need for more information about accidents and their causes. This lack of information is repeatedly a stumbling block in deciding how and where to direct efforts in improving safety. An accident reporting system such as the National Safety Council's Farm Department is now coordinating in a few states could be considered as the basis for a national system of retrieving accident information. Accident statistics and information can be especially helpful in tractor design and safety education. If factors that contribute to a particular type of accident are known, they can be considered in future designs and in educational programs.

In establishing priorities to improve safety, detailed accident information on a uniform basis is necessary. Adequate agricultural accident information is not available.

How should regulations be enforced?

The feasibility of establishing and measuring performance requirements would be a critical factor in effective certification or enforcement. If regulations are considered necessary, the resources of ASAE - technical deliberations and cooperative standards activities - can help establish performance requirements.

How should the retrofit problem be handled?

The need for, or feasibility of, retrofit will vary for the particular device or situation. Some ASAE Standards currently provide for interchangeability among various brands, models, and ages of machines and devices. This has been carefully worked out through the ASAE standardization procedures when practicable. Feasibility of retrofit is often technically complex and depends on several factors. For instance, retrofit of the SMV emblem (ASAE S276.2) is not difficult. Retrofit of a complete lighting and marking system for tractors and implements is more complicated. It is provided, where feasible, in ASAE S279.4, but it depends for one thing on whether older tractors have appropriate sources and outlets for electricity. Test work leading to development of overturn protection and current ASAE Standards indicates that retrofitting overturn protective structures would be much more difficult, and could impose additional hazards.

The feasibility of retrofit must be carefully evaluated for each device involved. It can be effectively considered through technical expertise of engineering societies such as the ASAE technical committees and cooperative standardization program provide.

Summary

The concern and activities of ASAE for agricultural tractor and equipment safety are of long standing and are well known. Its meetings, conferences, publications, committee activities, and standardization efforts have significantly improved agricultural safety.

The ASAE membership and organizational machinery provide unique resources of talents from industry, federal government, land-grant colleges and universities, farm organizations, and private enterprise for applying engineering to the needs of safety and environment in agricultural production.

The ASAE Cooperative Standards Program is well established. It is dynamic and effective as a means of voluntarily improving the safety of agricultural machines, nationally and internationally.

ASAE is accelerating the tempo of its activities to further improve agricultural safety. This is witnessed by the December 1969 commitment of the Agricultural Safety Committee to develop a plan for 50 percent reduction of agricultural accident fatalities by 1980. Further cooperation of all concerned parties for research on causes of accidents, and education for safe operation can also help reduce tractor accidents.

If Congress decides that federal regulations are necessary to improve specific areas of tractor safety, then the technical meetings, conferences, committees, and cooperative standards activities of ASAE are available to consider feasible engineering solutions on which regulations could be based.

APPENDIX I

COMMITTEES AND COOPERATIVE ACTIVITIES
OF THE
AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS
SOCIETY YEAR 1970-71

(Complete list of committees and committee personnel is carried in the 1970 edition of Agricultural Engineers Yearbook, pages 28-41)

* * * * *

COMMITTEES REPORTING TO THE SOCIETY EXECUTIVE COMMITTEE

E-1 Meetings
E-2 ASAE Foundation Trustees
E-3 Forward Planning
E-5 Engineers Joint Council
E-6 Engineers Council for Professional Development
E-7 Commission Internationale du Genie Rural
E-8 Architect's (New Building)

COMMITTEES REPORTING TO THE TECHNICAL COUNCIL

NON-DIVISIONAL COMMITTEES

T-1 Standards
T-2 Agricultural Safety
T-3 Instrumentation and Controls
T-4 Bioengineering
T-5 Computers

ELECTRIC POWER AND PROCESSING DIVISION

EPP-01 Executive
EPP-02 Steering
EPP-03 Standards
EPP-04 Paper Awards
EPP-05 Paper Screening
EPP-06 Program
EPP-33 Farm Wiring
EPP-41 Milk Handling Equipment
EPP-42 Electrical Controls for Farmstead Equipment
EPP-44 Electric Utilization Research Conferences
EPP-46 Farm Lighting
EPP-48 Radiation
EPP-49 Special Crops Processing
EPP-50 Stand-by Electric Power

FOOD ENGINEERING DIVISION

FE-01 Executive
FE-02 Steering
FE-03 Standards
FE-04 Publications
FE-05 Paper Screening
FE-06 Program
FE-07 Membership
FE-71 Education
FE-72 Nomenclature

POWER AND MACHINERY DIVISION

PM-01 Executive
PM-02 Steering
PM-03 Standards
PM-04 Publications
PM-05 Professional Development
PM-06 Professional Coordinating
PM-07 Program
PM-41 Agricultural Chemical Application
PM-42 Cultural Practices Equipment
PM-43 Farm Machinery Management
PM-44 Forage Harvesting
PM-45 Soil Dynamics Research
PM-46 Tractive and Transport Efficiency
PM-47 Tractor
PM-48 Fruit and Vegetable Harvesting
PM-50 Farm Materials Handling
PM-51 Tractor and Implement Hydraulic
PM-52 Small Tractor and Power Equipment
PM-53 Grain Harvesting
PM-54 Field Plot Research Equipment
PM-55 Forest Engineering
PM-57 Controlled Traffic for Crop Production

STRUCTURES AND ENVIRONMENT DIVISION

SE-01	Executive
SE-02	Steering
SE-03	Standards
SE-04	Papers Awards
SE-05	Paper Screening
SE-06	Program
SE-07	Research Needs
SE-08	CIGR Section II Relations
SE-201	Material of Construction
SE-202	Loads Imposed on Structures
SE-203	Analysis and Design
SE-204	Construction Engineering
SE-401	Family Housing
SE-402	Beef Housing
SE-403	Dairy Housing
SE-404	Swine Housing
SE-405	Poultry Housing Systems

SOIL AND WATER DIVISION

SW-01	Executive
SW-02	Steering
SW-03	Standards
SW-05	Publications Review
SW-07	Nomenclature

SW-21-HYDROLOGY GROUP

SW-211	Infiltration
SW-212	Runoff
SW-213	Evapotranspiration
SW-215	Watershed
SW-216	Groundwater
SW-217	Hydraulics of Watershed Development

SW-22-SOIL EROSION GROUP

SW-221	Terrace and Related Slope Modification Systems
SW-222	Conservation Tillage Methods
SW-223	Erosion Control Research
SW-224	Pollution by Sediment

SW-23-DRAINAGE GROUP

SW-231	Drainage Research
SW-232	Design and Construction of Tile Drains
SW-233	Surface Drainage
SW-234	Drainage of Irrigated Lands
SW-235	Highway and Agricultural Drainage
SW-236	Pump Drainage
SW-237	Drainage Materials

SW-24-IRRIGATION GROUP

SW-241	Sprinkler Irrigation
SW-242	Surface Irrigation
SW-243	Concrete Irrigation Pipe Systems
SW-245	Standards for Irrigation Wells
SW-246	Concrete Slip-Form Canal Linings
SW-247	Flexible Membrane Linings
SW-248	Irrigation Structure
SW-249	Subsurface Irrigation

JOINT TECHNICAL COMMITTEES

EPP-34	Farm Materials Handling (EPP, PM & SE)
EPP-38	Grain and Feed Processing and Storage (EPP & SE)
EPP-47	Physical Properties of Agricultural Products (EPP & PM)
SW-214	Water Treatment and Use (SW, EPP & SE)
SE-412	Agricultural Sanitation and Waste Management (SE & SW)
SE-300	ASHRAE Liaison (SE & EPP)
SE-301	Environmental Physiology (SE & EPP)
SE-302	Environment of Animal Structures (SE & EPP)
SE-303	Environment of Plant Structures (SE & EPP)
SE-304	Environment of Stored Products (SE, EPP & FE)

COMMITTEES REPORTING TO THE ADMINISTRATIVE COUNCIL

A-1 Constitution and Bylaws

AWARDS DEPARTMENT

A-110 Jury of Awards of Honor
A-111 Jury for the MBMA Award
A-112 Massey-Ferguson Educational Award
A-113 Jury for the Hancock Brick and Tile Soil and Water Engineering Award
A-114 George W. Kable Electrification Award
A-115 John Sutton Award
A-116 Paper Awards
A-117 Student Paper Awards
A-118 FIEI Student Trophies

EDUCATION AND RESEARCH DEPARTMENT

A-202 Steering
A-210 Extension
A-211 Research
A-212 Graduate Instruction
A-213 Curriculum and Course Content
A-214 Instruction in Agr. Mech.
A-215 Emergency Preparedness
A-216 Student Branches
A-217 Department Chairmen
A-218 Affiliated Student Clubs

FINANCE DEPARTMENT

A-310 Finance
A-311 Cooperative Standards Program
A-312 Agricultural Engineering Show Policy
A-313 Group Insurance
A-314 Advisory Committee to ASAE Foundation

PROFESSIONAL DEVELOPMENT DEPARTMENT

A-401 Executive
A-402 Steering
A-410 Public Relations
A-411 International Relations
A-412 Membership Election
A-413 Career Guidance
A-414 Engineering Registration
A-415 Agricultural Engineer's Relations in Civilian and Military Service
A-416 Continuing Education

PUBLICATIONS DEPARTMENT

A-510 Publications Policies and Finances
A-510/1 Monographs

COMMITTEE REPORTING TO THE REGIONAL COUNCIL

R-1 Membership Development

COOPERATIVE ACTIVITIES WITH OTHER ORGANIZATIONS

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, Member of Council

AMERICAN FEED MANUFACTURERS ASSOCIATION, Committee on Standard for Feed Mixing Test Procedures

AMERICAN FORAGE COUNCIL

AMERICAN NATIONAL STANDARDS INSTITUTE

Standards Committees:
- B6: Standardization of Gears
- B15: Safety Code for Mechanical Power-Transmission Apparatus
- B18: Standardization of Bolts, Nuts, Rivets, Screws and Similar Fasteners
- B29: Transmission Chain and Sprocket Teeth
- B92: Splines and Splined Shafts
- B93: Fluid Power Systems and Components
- B114: Agricultural Tractors and Agricultural Machinery
- B118: Overrunning Clutches
- C69: Safety Standards for Electrical Fence Controllers and Installations
- K61: Storage and Handling of Anhydrous Ammonia
- MH1: Standardization of Pallets
- O3: Pulpwood Logging Safety
- X3: Computers and Information Processing
- Y1, Y10, Y32: Graphic Symbols and Abbreviations
- Z11: Petroleum Products and Lubricants
- Z53.1: Safety Color Code

Member Body Council
Committee for International Standards Relations
Advisory Committee for ISO/TC 127, Earthmoving Machinery

AMERICAN SOCIETY OF HEATING, REFRIGERATION AND AIR CONDITIONING ENGINEERS

AMERICAN SOCIETY OF MECHANICAL ENGINEERS
Food, Drug and Beverage Equipment Committee

AMERICAN SOCIETY FOR TESTING AND MATERIALS
- ASTM Committee A-5; Corrosion of Iron and Steel
- ASTM Committee D-2; Petroleum Products and Lubricants
  - Tech.B: Automotive Lubricants
  - Tech.N: Hydraulic Fluids

COMMISSION INTERNATIONALE DU GENIE RURAL (CIGR-International Commission of Agricultural Engineering)
- Management Committee
- Correspondents to Technical Sections:
  - Sect. I, Soil & Water Sciences
  - Sect. II, Rural Construction & Related Equipment
  - Sect. III, Agricultural Machinery
  - Sect. IV, Rural Electrification
  - Sect. V, Scientific Organization of Agricultural Work

COUNCIL ON PESTICIDE APPLICATION

ENGINEERS COUNCIL FOR PROFESSIONAL DEVELOPMENT
- Board of Directors
- Engineering Education and Accreditation Committee
- Ethics Committee
- Executive Committee
- Guidance Committee
- Junior Engineering Technical Society, Technical Advisory Committee
- Personnel for Inspection Teams

ENGINEERS JOINT COUNCIL
- Board of Directors
- Commission on International Relations
- ENGINEER Editorial Advisory
- Engineering Manpower Commission
- General Assembly
- Metric Advisory Committee
- National Medal of Science, Nominating Committee

FARM AND INDUSTRIAL EQUIPMENT INSTITUTE
- Engineering Policy Committee

ILLUMINATING ENGINEERING SOCIETY
- Farm Lighting Committee

INSTITUTE FOR THE CERTIFICATION OF ENGINEERING TECHNICIANS
- Advisory Council

INSTRUMENT SOCIETY OF AMERICA
- Committee 8D-RP5.1, Instrumentation Flow Plan Symbols

NATIONAL ACADEMY OF SCIENCES, NATIONAL RESEARCH COUNCIL

NATIONAL BUREAU OF STANDARDS
- Standing Committee, CS238-61, Polyethylene Sheeting

NATIONAL COUNCIL OF ENGINEERING EXAMINERS

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

POULTRY SCIENCE ASSOCIATION
- Intersociety Committee on Environmental Quality
- Intersociety Research Animal Care Committee

SCIENTIFIC AGRICULTURAL SOCIETIES
- Policy Committee

SOCIETY OF AUTOMOTIVE ENGINEERS
- Tractor Technical Committee

VOLUNTEERS FOR INTERNATIONAL TECHNICAL ASSISTANCE, INC.

PRELIMINARY OUTLINE

APPENDIX II

ASAE SAFETY GOALS AND PLANS

The ASAE Agricultural Safety Committee (T-2) was asked to develop a Society-wide plan to help reduce fatal farm accidents 50% by 1980. The T-2 Safety Goals and Plans Subcommittee proposes a preliminary plan that would also be directed to reducing non-fatal accidents. Essentially, the challenge is for ASAE to systematically direct its engineering talents to accident prevention. On behalf of Committee T-2, The Safety Goals and Plans Subcommittee submits the following outline for action.

1. Define and evaluate accident and fatality situations.

    1.1 Select studies and statistics to be used as reference. Get outside help where appropriate. Establish starting points against which progress will be measured for fatal and non-fatal accidents. (National Center for Health Statistics and National Safety Council). Preferably work on rates (e.g. incident/exposure) when available, rather than numbers of accidents and deaths. Meanwhile use available data.

    1.2 Select data and forms to record progress.

    1.3 Establish procedures to evaluate progress and adjust efforts.

2. Identify types of accidents and potential problem areas in order of importance.

    2.1 Goals and Plans Subcommittee provide preliminary list (now being developed) of accident types and problem areas within ASAE's scope of interest.

    2.2 *Workshop of about 20 selected persons review preliminary list, suggest changes, and additions.

    2.3 Workshop prepare master list of accident types ranked by importance and opportunity for improvement.

3. Workshop examine the primary elements of each system: Man, environment, manufactured additives. List specific problems for each element.

4. Workshop identify problem areas of each element that can be improved by engineers and others. Give due attention to potential problems.

    4.1 Prepare two groups of problems:

        4.1.1 Problems that can be solved by engineering and ASAE efforts.

        4.1.2 Problems that should be referred to other organizations.

    4.2 Suggest specific solutions for each grouping (from 4.1) such as: ASAE standard; special conference with NIFS; encourage farm press to promote farmer use of a safety device; propose USDA research; ASAE technical session, etc.

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*A workshop has been scheduled for 13 and 14 October, 1970 at ASAE Headquarters, St. Joseph, Michigan

5. Workshop outline general plan to attack identified problem areas.

6. T-2 consolidate Workshop outline into proposal for ASAE Technical Council to approve in December 1970.

7. Divisions, committees, and geographic units implement plans, programs, etc. under coordination of Committee T-2 (for Technical Council).

8. T-2 advise other organizations of the problems that need their attention based on results of 4.1.2 and 4.2; also encourage cooperative efforts where appropriate.

9. T-2 continually review and evaluate progress, and update efforts.

The above preliminary plan also outlines the work to be done during the October Workshop. It will be reviewed during the Workshop and then refined before being submitted to the Technical Council in December, 1970.

P. L. Bellinger
Chairman, ASAE Agricultural Safety Committee T-2
and Safety Goals and Plans Subcommittee
19 August, 1970

APPENDIX III

American Society of Agricultural Engineers

C OOPERATIVE
S TANDARDS
P ROGRAM

The ASAE
COOPERATIVE STANDARDS PROGRAM

... Serving INDUSTRY and CONSUMER in AGRICULTURE

American Society of Agricultural Engineers • P.O. Box 229, St. Joseph, Michigan 49085

A MEMBER OF THE AMERICAN NATIONAL STANDARDS INSTITUTE

WHAT ARE THE OPPORTUNITIES FOR PARTICIPATION AND SUPPORT?

INDUSTRIES, ORGANIZATIONS related to agriculture and CONSUMERS benefit from ASAE Standards developed by experienced and qualified engineers through the Cooperative Standards Program. CSP provides a continuing opportunity for financial support of the principle of **voluntary standardization.**

Early in 1965 the U.S. Department of Commerce' Panel on Engineering and Commodity Standards submitted to the Secretary of Commerce a plan for increased activity in voluntary standardization. The plan recommended that ". . . industry groups and trade associations continue cooperation with others, through organizations providing balance of producer-consumer-public interests, in the development of standards of broad interest." ASAE has proven its effectiveness as a source of consensus standards for agriculture, and as a member body of the American National Standards Institute (formerly USASI), ASAE is active in the development of national interest standards.

In 1969 more than 290 companies and organizations recognized the need for continuing financial support of CSP and contributed a total of $23,315 toward the budget. Industry and consumer organizations recognize that standardization does not directly benefit the individual engineer, therefore individual membership dues paid to ASAE for individual membership services should not be a major source of support for the ASAE Cooperative Standards Program. As in previous years the program was subsidized from member dues, however, the cost of increased emphasis on standardization must be borne by concerned industry and consumer groups rather than by individual engineers.

The CSP Committee urges continued annual support of voluntary standardization. With necessary financial support ASAE can continue to provide the standardization services required for the increasingly complex engineered products and markets. A condensation of the budget for the 1970 Cooperative Standards Program follows:

CSP BUDGET FOR 1970

Expenditures:		
Employee costs		$16,300
Publication and Distribution expenses		14,100
Office expenses		4,000
Travel		1,400
Allocated overhead		6,100
	Total	$41,900
Income:		
Standards and Yearbook sales		$ 2,000
CSP contributions - Goal		39,900
	Total	$41,900

WHO IS INVITED TO SHARE FINANCIAL SUPPORT OF THE ASAE COOPERATIVE STANDARDS PROGRAM?

☐ Tractor and implement manufacturers

☐ Suppliers of materials and components for the tractor and implement industry

☐ Trade and educational associations representing agriculture-related industries

☐ Soil and water equipment manufacturers and suppliers

☐ Manufacturers and suppliers of electric power, farmstead equipment, and related feed handling and processing equipment

☐ Structures manufacturers and suppliers – animal shelter, food and feed storage

☐ Cooperatives and consumer organizations

☐ Agricultural insurance organizations

All of the above groups benefit from the standards, recommendations, and data developed and distributed through the ASAE Cooperative Standards Program. All are invited to share in the financial support of CSP, just as their engineers are invited to participate individually in ASAE committee activities.

CSP—HOW IT WORKS

ASAE's Cooperative Standards Program serves INDUSTRY and CONSUMER. Standardization documents developed through CSP assist in reducing manufacturing costs, broadening market potential; and improving compatibility, interchangeability, safety, and selection of products and materials. Here's how the program works:

☐ Any individual or organization may propose ASAE Standards, Recommendations, or Data, or may express the need for ASAE to develop or cooperate in developing standards.

☐ ASAE committees and liaison representatives to other organizations develop and maintain Standards, Recommendations, and Data.

☐ The committees include members or representatives from all interest groups known to be affected by each standardization item.

☐ ASAE maintains liaison and cooperative activity with other engineering societies such as Society of Automotive Engineers, American Society of Mechanical Engineers, American Society for Testing and Materials, and Illuminating Engineering Society.

☐ ASAE maintains liaison and cooperative activity with trade associations such as Farm and Industrial Equipment Institute, American Feed Manufacturers Association, and provides opportunity for similar organizations to participate.

☐ ASAE is represented on committees of the American National Standards Institute developing standards for such items as transmission chains and sprockets, electric fence controllers, splines, fluid power systems, petroleum products, graphical symbols, gears, fasteners, power transmission safety, and pulpwood logging safety. ASAE cosponsors ANSI Committee B114, Agricultural and Industrial Tractors and Machinery.

☐ Committee members and liaison representatives serve as technically qualified individuals.

☐ Participation in developing Standards, Recommendations, and Data is voluntary. Compliance with ASAE standardization documents is also voluntary.

☐ ASAE publishes and distributes its Standards, Recommendations, and Data for world-wide use.

THROUGH THE COOPERATIVE STANDARDS PROGRAM. . .

ASAE Standards, Recommendations, and Data are developed to reflect the interests of industry, consumer, and the public.

ASAE has a voice in the development of standards by other organizations with related interests.

ASAE STANDARDS, RECOMMENDATIONS, DATA —

What They Do for Industry and Consumer

ASAE Standards, Recommendations, and Data are developed and maintained through the Cooperative Standards Program. They serve INDUSTRY and CONSUMER by helping to provide:

INTERCHANGEABILITY among interfunctional products manufactured by two or more organizations. This improves mechanical compatibility, safety of operation, and performance.

REDUCTION IN VARIETY OF COMPONENTS required to serve an industry, thus improving availability and economy for manufacturer and consumer.

SAFE PERFORMANCE, INSTALLATION, OR APPLICATION of products and materials.

ACCEPTED ENGINEERING PRACTICES for design and application.

INCREASED EFFICIENCY of engineering effort in design and production resulting in direct savings in engineering, production, and service costs.

UNIFORM TERMINOLOGY for describing or advertising performance and characteristics of products and materials.

DATA for research, design, and application.

A SOUND BASIS FOR CODES, LEGISLATION, EDUCATION related to the agricultural industry Promotes uniformity of practice among states.

A VOICE IN INTERNATIONAL STANDARDS. ASAE Standards, expressing the consensus of United States manufacturers, have been accepted as draft proposals by the ISO (International Organization for Standardization).

INTERNATIONAL MARKETING ADVANTAGE. ASAE Standards, submitted as the basis for world-wide standards, can help reduce the variety and number of production runs required for world-wide marketing. This can improve the competitive position of United States manufacturers.

EXAMPLES –

How Some of the CSP Activities Serve Industry and Consumer in Agriculture

Tractor Operator Protection

ASAE S306, ASAE S310 and ASAE S336 serve as a basis for design and performance testing of frames and enclosures for the protection of tractor operators from injury resulting from accidental upset and from overhead hazards. These standards are major engineering inputs to reduction of fatal farm accidents.

Single-Phase Service for Large Motors

ASAE R329, Single-Phase Rural Distribution Service for Motors and Phase Converters, promotes uniformity in rural single-phase service regulations and promotes the design and use of larger electric motor operated equipment.

Electric Heating Installations

An ASAE recommendation on electric infrared brooding equipment helped power suppliers, educators, and insurance companies, promote adequate wiring and installation of infrared head units in farm buildings for the benefit of industry and consumers.

Slow-Moving Vehicle Emblem

ASAE Standard S276, Slow-Moving Vehicle Identification Emblem, defines usage of and specifications for a unique identification of slow-moving vehicles. It is one more step toward uniform procedures for marking slow-moving vehicles to help minimize highway accidents. Many states have adopted legislation based on this standard. ASAE S276 is referenced in the Uniform Vehicle Code and Model Traffic Ordinance.

Symbols for Operator Controls

Symbols for operator controls enhance foreign markets by breaking the language barrier. They permit the use of more compact control panels with safety. ASAE R304 establishes uniform symbols for agricultural and industrial tractors.

Steel Grain Storage Tanks

Many engineers from related industries enthusiastically joined in an ASAE committee to develop the ASAE recommendation on steel grain storage tanks. Their concern and efforts, to prevent failure of grain storage bins, resulted in a recommendation that will help eliminate use of improper materials, poor building techniques, and inadequate foundation design.

Small Tractor and Power Equipment Projects

Manufacturers of small tractors and power equipment are participating in developing standardization through ASAE committees for horsepower ratings, safety, hitches, hydraulic systems, and PTO's. The results include many benefits to supplier, manufacturer, and consumer in terms of economics, safety, convenience, and availability. ASAE S320T, Category "O" Three-Point Free-Link Attachment for Hitching Implements to Lawn and Garden Riding Tractors up to 20 Horsepower, and ASAE S298, Drawbar for Lawn and Garden Tractors, are examples.

Snow and Wind Loads for Buildings

Recommendation R288, Designing Buildings to Resist Snow and Wind Loads, presents data on distribution of probable snow and wind loads, and methods of applying them to building design. R288 helps eliminate the old problem of estimating snow pack density. It also includes sections on shape coefficients for external wind loads.

See current activities on back cover —

Lighting and Marking of Agricultural Equipment

ASAE Standard S279, Lighting and Marking of Agricultural Equipment and Industrial Equipment on Highways, is of national concern. This standard promotes effective lighting of agricultural equipment to help reduce the number of accidents on highways. It will help the manufacturer, the user, and the general public.

Metric Units

The ASAE recognizes a genuine and increasing requirement for improving compatibility of specifications and products manufactured by metric and English units. Recommendation ASAE R285, Use of English and Metric Units, was developed by technical committees to improve communications involving the two systems.

Drainage and Irrigation

The ASAE recommendation on tile drains and the standard on concrete irrigation pipe systems guide engineers who design the systems. This helps insure proper application of the tile and pipe, thus helping the profession, manufacturers, and users of products and equipment.

An ASAE recommendation on sprinkler irrigation equipment, developed cooperatively with the Sprinkler Irrigation Association, outlines proper design, installation and performance, and dealer-purchaser responsibilities. By helping provide proper application and installation of equipment, it helps industry and consumer.

Crop Drier Standard

The ASAE standard on crop drying equipment helped the industry alleviate some of its problems by promoting efficiency and safety in design, construction, installation, rating, and use of heated air crop driers. Industry and consumers share the benefits.

Irrigation Canal Linings

Where concrete canal linings are adaptable, universal acceptance of an ASAE standard recently published will enable manufacturers to standardize excavating and lining equipment. This will help reduce costs of special engineering and equipment manufacturing. This will help lower the total cost of completed linings.

Lighting for the Poultry Industry and Dairy Farms

Sanitation, safety, and efficient operation frequently suffer because of inadequate lighting. Joint ASAE-IES lighting recommendations have been developed to improve operations, economy, and product quality in dairy and poultry industries.

Power Take-Offs for Tractors

Standards and recommendations for 540 and 1000-rpm power take-offs permit almost unlimited interchangeability and improved driveline shielding among all makes and models of tractors and implements built by the standards - whether of domestic or foreign manufacture - benefiting industry and consumer.

Tractor and Implement Hitches

ASAE standards on three-point hitches and quick couplers permit attaching nearly any type of three-point implement to the three-point hitch on any make or model of tractor. This helps domestic and foreign manufacturers of such implements and tractors, including shortline companies. It permits the consumer to select implements of appropriate size, type, price, and brand from among many manufacturers to use with the tractor of his choice.

CSP ACTIVITIES — 1969 PROGRESS REPORT

New Standards Adopted:

ASAE S322, Uniform Terminology for Farm Machinery Management
ASAE S323T, Definition of Lawn and Garden Riding Tractor, Lawn Riding Tractor, and Riding Lawn Mower
ASAE S324T, Volumetric Capacities of Box Type Manure Spreaders-Dual Rating Method
ASAE S325, Volumetric Capacities of Open Tank Type Manure Spreaders
ASAE S326, Volumetric Capacities of Closed Tank Type Manure Spreaders
ASAE S327, Uniform Terminology for Pesticide Spraying
ASAE S328T, Dimensions for Compatible Operation of Forage Harvesters, Forage Wagons, and Forage Blowers
ASAE R329, Single-Phase Rural Distribution Service for Motors and Phase Converters
ASAE R330, Procedure for Sprinkler Distribution Testing for Research Purposes
ASAE R331T, Implement Power Take-Off Drive Lines
ASAE R332, Poultry Industry Lighting
ASAE R333, Agricultural Tractor and Industrial Tractor Auxiliary Power Take-Off Drives
ASAE S334T, Dimensioning Standards for Permanently-Installed Screw Conveyors
ASAE R335, Operator Controls on Agricultural Equipment and Industrial Equipment
ASAE S336, Protective Enclosures — Test Procedures and Performance Requirements

Standards Revised:

ASAE S203.7, 540-RPM Power Take-Off for Agricultural Tractors
ASAE S204.6, 1000-RPM Power Take-Off for Agricultural Tractors
ASAE R207.7, Operating Requirements for Power Take-Off Drives
ASAE S229.4, Baling Wire for Automatic Balers
ASAE S237.1, Volumetric Capacities of Manure Spreaders
ASAE D270.3, Design of Ventilation Systems for Poultry and Livestock Shelters
ASAE S279.4, Lighting and Marking of Agricultural Equipment and Industrial Equipment on Highways
ASAE R288.2, Designing Buildings to Resist Snow and Wind Loads
ASAE S303.1, Test Procedure for Solids-Mixing Equipment for Animal Feeds
ASAE R304.2, Universal Symbols for Operator Controls on Agricultural and Industrial Tractors and Equipment
ASAE S305.2, Operator Protection for Wheel Type Agricultural and Industrial Tractors
ASAE S306.2, Protective Frame Test Procedures and Performance Requirements
ASAE S310.1, Protective Frame with Overhead Protection — Test Procedures and Performance Requirements
ASAE R318.1, Safety for Agricultural Equipment and Industrial Wheeled Equipment

Standards Being Developed as of December 1969:

Standard on tobacco bulk curing racks
Data on flowability of grain and other bulk solids
Recommendation for calibrating agricultural sprayers
Standard procedure for testing fertilizer spreaders
Standard for plow sweep and shovel mountings
Standard weight capacity ratings for farm trailers and wagons
Standard on safety chains for agricultural implements
Recommended practices for milking systems
Standard for construction and installation of automatic electric livestock waterers
Standard for auger flights
Standard for pulpwood logging safety
Standard on brakes for agricultural machinery
Standard on hitches for forestry tractors
Standard for hydrostatic power outlets
Safety recommendation for lawn and garden tractors
Standard combine terminology
Standard for forage blower pipe flanges
Standard procedure for handling liquid and suspension fertilizer
Standard for large implement tool bars
Data on agricultural machinery costs and use
Standard on agricultural pallet bins
Standard on capacity and dumping height of cotton harvester baskets
Standard power take-off drives for small tractors
Standard on remote control cylinders and electromechanical actuators for lawn and garden tractors
Standard on front mounting hitch points for lawn and garden tractors
Safety standard on farmstead equipment
Recommendation on agricultural loader stability
Standard procedure for testing airtight storage structures
Standard on rating of controlled atmosphere generators
Standard terminology for drum and spray driers
Conversion factors for heat and mass transfer rates
Standard on moisture measurement
Standard on water hardness
Standard on water quality for livestock
Recommendation on installation of flexible membrane linings for ponds and reservoirs

Many of the above projects involve cooperative effort with other organizations.

APPENDIX IV

ASAE STANDARDS AND RECOMMENDATIONS WITH SAFETY PROVISIONS FOR TRACTORS AND IMPLEMENTS

*S203.7, 540-RPM Power Take-Off for Agricultural Tractors; Adopted April 1927.

*S204.6, 1000-RPM Power Take-Off for Agricultural Tractors; Adopted in 1958.

*R333, Agricultural Tractor and Industrial Tractor Auxiliary Power Take-Off Drives; Adopted December 1969. (Supersedes R206, adopted March 1955, and R311, adopted December 1968)

*R207.7, Operating Requirements for Power Take-Off Drives; Adopted March 1953.

*S297T, Full Shielding of Power Drive Lines for Agricultural Implements and Tractors; Adopted June 1966.

R331T, Implement Power Take-Off Drive Lines; Adopted December 1969.

R314, Implement Power Take-Off and Drive Line Pedestal Shafts; Adopted December 1968.

*R208, Definition of Reportable Accident; Adopted in 1959.

S216, Self-Powered Electric Warning Lights; Adopted in 1961.

*S279.4, Lighting and Marking of Agricultural Equipment and Industrial Equipment on Highways; Adopted December 1964. (Supersedes S213, adopted in 1954)

*S307, Flashing Warning Lamp for Remote Mounting on Agricultural and Industrial Equipment; Adopted December 1967.

*S277.1, Mounting Brackets and Socket for Agricultural and Industrial Equipment Warning Lamp and Slow-Moving Vehicle (SMV) Identification Emblem; Adopted December 1964.

*S276.2, Slow-Moving Vehicle Identification Emblem; Adopted December 1964.

R317, Improving Safety on Enclosed Mobile Tanks for Transporting and Spreading Agricultural Liquids and Slurry; Adopted December 1968.

*R318.1, Safety for Agricultural Equipment and Industrial Wheeled Equipment; Adopted December 1968. (Supersedes R275 and R280, adopted in 1964)

*S305.2, Operator Protection for Wheel Type Agricultural and Industrial Tractors; Adopted August 1967.

*S306.2, Protective Frame - Test Procedures and Performance Requirements; Adopted August 1967.

*S310.1, Protective Frame with Overhead Protection - Test Procedures and Performance Requirements; Adopted June 1968.

*S336, Protective Enclosures - Test Procedures and Performance Requirements; Adopted February 1970.

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* Pertains to agricultural tractors.

ASAE Standards and Recommendations with Safety Provisions for Tractors and Implements (Cont'd)

*S217.6, Three-Point Free-Link Attachment for Hitching Implements to Agricultural Wheel Tractors; Adopted March 1959.

*S278.2, Attachment of Implements to Agricultural Wheel Tractors Equipped with Quick-Attaching Coupler for Three-Point Free-Link Hitch; Adopted December 1964.

*R220.2, Tire Selection Tables for Agricultural Machines of Future Design; Adopted in 1961.

*S295.1, Agricultural Tractor Tire Loading and Inflation Pressures; Adopted June 1965.

*R335, Operator Controls on Agricultural Equipment and Industrial Wheeled Equipment; Adopted December 1969. (Supersedes R234 and R235, adopted 1962)

*R304.2, Universal Symbols for Operator Controls on Agricultural and Industrial Equipment; Adopted June 1967.

S328T, Dimensions for Compatible Operation of Forage Harvesters, Forage Wagons and Forage Blowers; Adopted December 1969.

*S301, Front-End Agricultural Loader Ratings; Adopted December 1966.

S248.1, Construction, Installation, and Rating of Equipment for Drying Farm Crops; Adopted December 1962.

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* Pertains to agricultural tractors.

ASAE TECHNICAL PAPERS ON TRACTOR SAFETY FROM 1960-1970

Safety and Comfort Tests Program - Swedish Approach, Paper No. 70-105.
Simulation of Tractor Overturns, Paper No. 70-150.

The Need for a Maximum Noise Level Standard for Farm and Construction Equipment Operators, Paper No. 69-119.
Effect of Environmental Factors on Human Performance, Paper No. 69-511.
Identifying Accident Corrective Measures Through New Analytical Methods, Paper No. 69-592.
Looking at Human Behavior for Clues to Man-Machine Problems, Paper No. 69-593.
Corporate Product Safety - Farm and Industrial Machinery, Paper No. 69-594.
A Study of Tractor Overturning Accidents, Paper No. 69-639.
Development and Related Standards Activities of a Hitch Safety Chain for Agricultural Equipment, Paper No. 69-649.
Development of a Fully Shielded Universal Joint, Paper No. 69-651.
Small Tractor Operator Position and Safety Behavior, Paper No. 69-673.
Man-Machine Compatibility, AGRICULTURAL ENGINEERING, January 1969, pages 17-19, 21.
Tractor Cab Suspension Design and Scale Model Simulation, TRANSACTIONS OF THE ASAE, Vol. 12, No. 3, pages 283-285, 289, 1969.

Verification of a Mathematical Model to Predict Tractor Tipping Behaviors, Paper No. 68-107.
Improvements in Farm Tractor Lighting and Marking, Paper No. 68-108.
Development of a Protective Roll-Over Standard Test Code for Agricultural and Light Industrial Tractors in the U.S., Paper No. 68-110.
Engineering a Modern Steel Cab, Paper No. 68-111.
Human Factors Engineering for Agriculture's Man-Machine Systems, Paper No. 68-512.
Principles of Human Engineering and Their Application by the Agricultural Engineer, Paper No. 68-563.
Interaction Between Man and Environment by a Study of Farm Accidents, Paper No. 68-564.
Reducing Human Error in Man-Machine Systems in Agriculture, Paper No. 68-565.
Results of Tractor Canopy Tests, Forest Engineering Conference Proceedings PROC-368, pages 19-22, 24, September 1968.

Tractor Noise and Operator Performance, Paper No. 67-122.
SMV (Slow-Moving Vehicle) Emblem, Paper No. 67-407.
Safety in Design and Operation of Farm Equipment - The Manufacturer's Concern, Paper No. 67-408.

European Experiences with Operator Protection Frames, Paper No. 66-624.
Design and Evaluation of a Protective Canopy for Agricultural Tractors, Paper No. 66-625.
Cabs for Farm Tractors, Paper No. 66-626.

Technical Papers on Tractor Safety from 1960-1970 (Cont'd)

Noise and Its Effect on Man, Paper No. 65-607.
Are Tractors Noisy? Paper No. 65-608.
Load Conditions for Maximum Muscle-Power Output, Paper No. 65-612.

Methods and Techniques for Identifying Slow-Moving Vehicles on Highways, Paper No. 62-139.
Prepared Discussion, Paper No. 62-140.
A Utility Roll Bar, Paper No. 62-632.
Design Criteria for Driver Safety Frame, Paper No. 62-633.
Antiroll Bars on Wheel Tractors and Mowers, The North Dakota Picture, Paper No. 62-658.
Prepared Discussion on Roll Bars for Tractors, Paper No. 62-659.

The Man-Machine Relationship to Tractor Accidents, Paper No. 61-128.
An Analysis of 212 Fatal Ohio Farm Tractor Accidents, Paper No. 61-129.
The Effects of Tractor Vibration Upon Operator Work Performance, Paper No. 61-131.
The Dynamic Behavior of Farm Tractors, TRANSACTIONS OF THE ASAE, Vol. 4, No. 2, pages 215-218, 221, 1961.

The Cost and Extent of Farm Machinery Accidents, Paper No. 60-110.
Epidemiological Study of Tractor Accidents, Paper No. 60-111.
Safety - By Regulation or Education, Paper No. 60-114.
A New Law Concerning Lighting of Slow Moving Vehicles in Ohio, Paper No. 60-115.

Effect of Tractor Operation on Human Stresses, AGRICULTURAL ENGINEERING, September 1959, pages 510-519, 525.

Report to Department of Transportation

THE SOCIETY OF AUTOMOTIVE ENGINEERS PROGRAM ON STANDARDIZATION FOR AGRICULTURAL TRACTORS

September 25, 1970

REPORT TO DOT ON STANDARDIZATION FOR AGRICULTURAL TRACTORS

The Society of Automotive Engineers has prepared this presentation in response to a letter dated August 27, 1970, from Mr. Douglas W. Toms, Director of the National Highway Safety Bureau. The following is quoted from Mr. Toms' letter: "Because of the long interest of your Society in improving the safety of those who work with farm equipment, the Society is invited to prepare a paper. We are particularly interested in having you address the subject of standards for agricultural tractors.

"We hope that the following major points will be covered within the subject area:

a. Current standards, including those in process, that affect agricultural tractors, including a discussion of the organizations involved in the standard setting process.

b. Whether Federal Agricultural Tractor Safety Standards are required and, if so, in what areas they should be prepared, by whom, in what order of priority and how such standards should be enforced.

c. How the retrofit problem should be handled."

Commencing with the merger of the Society of Automobile Engineers, the American Society of Aeronautic Engineers and Society of Tractor Engineers to form the present Society of Automotive Engineers (SAE) in 1916, the Society has been a leader in establishing a climate conducive to the solution of common technical problems. The term "automotive" is intended to cover "any self-propelled vehicle running on land, in or under the water, or in the air." In recognition of the various fields in which SAE members are employed or have an interest, the

Society (SAE) was organized into several divisions and technical councils.

Even in the early days of the Society, the divisions which included the tractor engineers conducted meetings during which technical papers were presented covering the technical problems of the day. Some of the discussions eventually led to the formation of "standards" which set forth suitable solutions based on the state of the engineering art at that time.

Effectiveness of the SAE Cooperative Engineering Program, under which standards and specifications are developed, stems in large measure from several basic SAE policies. For example:

1. Voluntary usage ... Standards, specifications and recommended practices developed by SAE committees are available to all for voluntary use or acceptance. There is no compulsion for anyone to adhere to these recommendations.

2. Individual membership, not company representation ... Members of SAE committees act as individuals in their Society participation. This is expressed by an SAE Bylaw, which says: "Individuals are elected or appointed to SAE committees on the basis of their personal qualifications and their ability to contribute to the work of these committees. In discharging their responsibilities, members of all SAE bodies -- organized to carry on the Society's work -- function independently as individuals, and not as agents or representatives of their employers."

3. Technical competence is the prime requirement ... Leading specialists in a committee's field of work are invited to serve on SAE committees. They need not necessarily be SAE members, or even engineers. Medical doctors, chemists and metallurgists are among those who have served on SAE technical committees. Thus, SAE appoints to its committees the most competent men available who can contribute to the solution of the problem under consideration.

4. A voice for all concerned ... Recommended standards and related documents developed by SAE committees represent a consensus of all those substantially concerned. Proposals are broadly circulated to assure input from all with an interest in the subject of the document.

5. Limited to engineering problems ... SAE restricts its standardization work to technical and engineering problems. Matters involving trade or buyer-seller relationships, or those which impinge on proprietary prerogatives of a company are inappropriate for SAE consideration.

The Society's involvement in standards for agricultural tractors goes back to 1917 when SAE formulated a standard for tractor belt speed and pulley width which was followed in 1923 with a standard for tractor power take-off.

In 1943, a technical committee for agricultural tractors was formed under the Automotive Council and was called the Tractor Technical Committee (TTC). A copy of the rules and regulations governing the operation of the technical committees, councils and the Technical Board is available upon request from SAE Headquarters. Members of the SAE Tractor Technical Committee are appointed for a three-year period.

Until 1970, the TTC was responsible for standards involving both agricultural tractors and "light" industrial tractors. "Light" industrial tractors were defined as those agricultural tractors which have been modified to perform certain types of non-agricultural work such as landscaping, highway mowing or digging and loading operations on construction jobs. Due to the non-agricultural operation of these tractors, the responsibility for these tractors has now been assigned to another SAE Committee -- the Construction and Industrial Machinery Committee. When reviewing some of the current agricultural tractor standards, it will be noted that they apply to both agricultural and industrial tractors. It is anticipated that in the next few years, SAE agricultural tractor standards no longer will apply to tractors modified for non-agricultural work.

The basic responsibility for developing standards for agricultural tractors has been delegated to the TTC. The authority for the final approval of these standards had, until recently, been delegated to the Automotive Council. In view of the large volume of work and the special knowledge required for evaluation of tractor standards, a new council has been established -- the Agricultural and Construction Machinery Council (ACMC). The new Council has been assigned the authority for final approval of all agricultural tractor standards.

SAE classifies standards into two categories as follows:

1. "Standards are documentations of sound, established, and broadly accepted engineering practices."
2. "Recommended Practices are documentations of data that are intended as guides toward standard engineering practice. Their content may be of a more general nature or they may propound data that have not yet gained broad acceptance."

In the area of safety, the TTC has adopted a policy of developing effective and attainable performance requirements rather than "minimum requirements." While undoubtedly there is room for improvement in the agricultural tractor standards, the Society is of the opinion that these standards have done much to promote overall safety in the use of the agricultural tractor. The application of the SAE standards to the tractors produced by the industry is outstanding.

The TTC appointed subcommittees to develop many of its proposals for standards. This is done to make use of the expertise available on the particular subject under consideration. Cooperation and assistance is secured from other committees within SAE, such as the automotive lighting committees, Human Factors, Safety, Air Pollution and others. Cooperation and assistance is also secured from organizations outside of SAE such as the American Society of Agricultural Engineers (ASAE), the Nebraska Tractor Testing Stations, the Tire and Rim Association, the Farm and Industrial Equipment Institute, International Standards Organization, Universities, Research Stations, and other outside non-industrial groups having technical expertise. Many of the proposals for standards are submitted by the Engineering Committee of the Farm and Industrial Equipment Institute. Some proposals involve tractors, farm implements, and self-propelled equipment.

Attached as Appendix A is a summary of SAE standards concerning safety requirements for agricultural tractors. The standards are identified by the SAE number, title, a brief summary of contents, and the original publication date.

Attached as Appendix B is a complete set of up-to-date SAE standards for agricultural equipment.

A Handbook of up-to-date SAE standards is published yearly. Those standards approved after the Handbook printing date are available from SAE Headquarters upon request.

Proposed standards currently under development which involve safety are as follows:

1. Agricultural Tractor Braking Test Procedure and Performance Requirements.
2. Turn signals for agricultural tractors.
3. Protective frame for forestry tractors.

Not only is the TTC working on new proposals, current standards are continually being reviewed and revised to reflect current technology. It is an SAE requirement that all standards be reviewed at least once every five years.

A major contribution to agricultural tractor safety over the last four years has been the development of the testing procedures and performance requirements for tractor operator protective frames and enclosures. Four standards concern this item. One standard concerns seat belts. The other three concern different types of operator protective devices. Whether the manufacturer wishes to make available the roll-bar, safety cab, or the European type safety frame, a standard for testing and specifying the performance requirements is available. Tractor protective frames may appear to be simple engineering jobs, but this is not necessarily true. Protective frames must be designed to be compatible with the strength of the tractor chassis. Protective frames not properly designed could cause failure in tractor components which could result in serious injury to the operator. For this reason it is most important that protective frames be tested in accordance with good testing procedure and meet a high performance requirement. Such testing procedures and performance requirements are established in the above-mentioned standards.

Federal Agricultural Tractor Safety Standards

SAE is an organization of professional individuals who work together to find solutions to technical problems which will lead to a better product for both the consumer and society. Thus, SAE is not in a position to comment as to whether any particular technical requirements should become purchase specifications. Whether a Federal Standard, which implies a purchase specification, should be required or not depends upon the results of field studies which clearly establish a public safety need for minimum performance requirements. The selection of appropriate areas, priority and enforcement are clearly the responsibility of enlightened public bodies who gain authority to establish purchase specifications from those they serve.

Because of SAE's large membership and expertise available in technical areas, the Society is qualified and willing to offer technical expertise and assistance in preparation of proposals for Federal Agricultural Tractor Safety Standards should the need for such standards be established.

Problem of Retrofit

The retrofit problem is one on which the Society is not qualified to comment because of considerations beyond its competence. Retrofit considerations hinge on whether there should be public action, in response to a possible public need, to cause owners of all or certain tractors to modify them. Should such a public need be established, it would be necessary to consult manufacturers of retrofit devices as to the feasibility of providing the necessary modifications and the methods of doing this. The feasibility of using technical performance requirements for new tractors would also have to be considered.

Extensive field research must precede decisions about retrofit problems; that is because of the wide diversity of products in use, their state of maintenance and varied conditions under which they operate, economic conditions of agriculture in general and the customer in particular.

Because of these considerations involved in the retrofit problem, SAE is not in a position to contribute to these deliberations -- except to the extent of making available its technical expertise.

If SAE can be of further assistance, the Society would be more than willing to assist within its capabilities and resources.

SAE STANDARDS INVOLVING SAFETY ON AGRICULTURAL TRACTORS

	SAE #	Title	Original SAE Approval Date
1.	J720	Tractor Belt Speed and Pulley Width	1917

This standard provides for a standard tractor belt pulley width and speed to reduce farmer confusion and consequently improve safety by having a uniform belt speed for operating different types of belt driven machinery.

2.	J716a	Application of Hydraulic Remote Control to Farm Tractors and Trailing Type Farm Implements	1949

The purpose of this standard is to establish common mounting and clearance dimensions for remote control cylinders and trailing type farm implements to facilitate changing hydraulic cylinders from one implement to another and to permit using the remote cylinders supplied by the tractor with any make or model of trailing implement. Safety is improved through uniformity in use of the remote cylinders and their mounting.

3.	J718c	540-RPM Power Take-Off for Farm Tractors	1923

This standard established the specifications that are essential in order that any 540 rpm power take-off driven machine may be operated with any make or model of tractor having a 540 rpm power take-off. The requirements for PTO safety shielding on tractors and implements are included in this standard.

4.	J719c	1000-RPM Power Take-Off for Farm Tractors	1958

This standard is similar to SAE 718c except it covers power take-off operating at 1000 rpm. Safety shielding is also specified both for the tractor and the implement.

5.	J721d	Operating Requirements for Power Take-Off Drives	1953

This standard was prepared to assist manufacturers of tractors and pto driven machines in providing suitable means of power transmission from the tractor to the driven machine. Load limitations are established for different size tractors and requires the manufacturer to provide safety instructions.

SAE STANDARDS INVOLVING SAFETY ON AGRICULTURAL TRACTORS

	SAE #	Title	Original SAE Approval Date
6.	J717a	Farm Tractor Auxiliary Power Take-Off Drives	1955

This standard specifies the speed and direction of rotation for power take-offs on tractors other than those located at the rear of the tractor. Confusion is reduced through standardization and consequently safety is improved.

7.	J722a	Power Take-Off Definitions and Terminology for Farm and Light Industrial Tractors	1954

This standard establishes the definitions and terminology pertaining to power take-off shafts on agricultural tractors to avoid confusion and consequently improve safety.

8.	J955a	Full Shielding of Power Drivelines for Agricultural Implements and Tractors	1966

This standard establishes the specifications for a fully shielded power take-off line for both towed and integral machines.

9.	J907	Recommendations for Improving Safety on Farm Tractors	1966

This standard specifies many items for reducing the possibility of personal injury while servicing and operating agricultural tractors. Items specified are foot pedals, operator floor material, handholds, ladders, steps, shielding for rotating parts, fenders, safety glass in cabs, and a number of other items.

10.	J708a	Agricultural Tractor Test Code	1956

This is the test code used by the Nebraska Tractor Testing Station. It determines the maximum power performance of a tractor. These tests determine that the tractor is designed to produce the advertised power and perform in a safe and satisfactory manner under varying load conditions.

SAE STANDARDS INVOLVING SAFETY ON AGRICULTURAL TRACTORS

	SAE #	Title	Original SAE Approval Date
11.	J707a	Spark Arresters for Internal Combustion Engines	1951

This specification covers the efficiency and endurance life of spark arresters used on internal combustion engines for the purpose of preventing the emission of glowing carbon particles that would ignite combustible material of the nature found in forest, grain and grass fields.

12.	J943a	Slow-Moving Vehicle Identification Emblem	1966

The standard is to establish the design and performance specifications for the Slow Moving Vehicle Emblem, which is a unique reflective emblem used on farm machinery to warn approaching traffic from the rear.

13.	J725a	Farm Equipment Safety Lamp Bracket	1954

This standard provides the specifications for standard brackets and sockets that are used for mounting the Slow Moving Emblem and Remote Mounted safety lights on the tractors.

14.	J908	Lighting and Marking of Farm and Light Industrial Equipment on Public Roads	1967

The purpose is to provide lighting and marking requirements for agricultural tractors whenever operating on public roads.

15.	J723a	Farm Equipment Breakaway Connector	1952

This standard covers a breakaway connector for lighting kit on pull behind equipment for farm tractors.

16.	J974	Flashing Warning Lamp for Farm and Light Industrial Equipment	1967

This standard establishes the specifications and test requirements that the flashing warning lamp must meet to be considered suitable for use on agricultural tractors.

SAE STANDARDS INVOLVING SAFETY ON AGRICULTURAL TRACTORS

	SAE #	Title	Original SAE Approval Date
17.	J975	Headlamps for Farm and Light Industrial Equipment	1967

This standard establishes the specifications and test requirements for headlights used on agricultural tractors to determine their adequacy for use on highways.

	SAE #	Title	Original SAE Approval Date
18.	J976	Combination Tail and Floodlamp for Farm and Light Industrial Equipment	1967

This standard establishes the specifications and test requirements for a combination tail and floodlamp to be considered adequate for its purpose.

	SAE #	Title	Original SAE Approval Date
19.	J709a	Agricultural Tractor Tire Loading and Inflation Pressures	1959

This standard establishes the tire loading and inflation pressures relationships for tire sizes and ply ratings when used on agricultural tractors.

	SAE #	Title	Original SAE Approval Date
20.	J715c	Three Point Free Link Hitch Attachment of Implements to Agricultural Wheeled Tractors	1959

This standard sets forth the requirements for the attachment of three point hitch implements to the rear of agricultural tractors. This hitch permits easy attachment and operation of implements which contributes to easier and safer operation of the tractor and implement conbination.

	SAE #	Title	Original SAE Approval Date
21.	J909a	Attachment of Implements to Agricultural Wheeled Tractors Equipped with Quick Attaching Coupler for Three Point Free Link Hitch	1966

This standard provides the specifications for a quick attach type coupler for attaching heavy implements to the three-point hitch on large tractors. It reduces the operator strain when hitching heavy implements to tractors and consequently contributes to his safety.

SAE STANDARDS INVOLVING SAFETY ON AGRICULTURAL TRACTORS

	SAE #	Title	Original SAE Approval Date
22.	J841b	Operator Controls on Farm and Light Industrial Tractors	1963

This standard is intended to reduce the possibility of operator confusion by providing guidelines for the uniformity and direction of motion of operator controls located in the vicinity of the operator's seat on agricultural tractors.

23.	J333	Operator Protection for Agriculture and Light Industrial Tractors	1968

This standard establishes requirements for the protection of operators on wheel type agricultural tractors to minimize the possibility of operator injury resulting from tractor upsets. Three types of protective devices are specified. The seat belt requirements are defined as well as a number of other safety requirements.

24.	J334	Protective Frame - Test Procedure and Performance Requirements	1968

This standard establishes the test procedure and performance requirements for the roll-bar type protective frame on agricultural tractors. The purpose of this standard is to provide a reasonable performance level for this operator safety device.

25.	J167	Protective Frame - Test Procedure and Performance Requirements	1970

This standard establishes the test procedure and performance requirements for the four post type of safety frame that includes overhead protection. This test is similar to that of the roll-bar type protective frame except that it includes a test of the roof to ensure reasonable operator protection.

SAE STANDARDS INVOLVING SAFETY ON AGRICULTURAL TRACTORS

	SAE #	Title	Original SAE Approval Date
26.	J168	Protective Enclosure - Test Procedure and Performance Requirements	1970

This standard establishes the test procedure and performance requirements for protective enclosure (cabs) for the protection of operators on agricultural wheeled tractors to minimize the possibility of operator injury resulting from accidental upsets. Reasonable levels of performance are established to ensure that a cab may be classified as a safety cab as differentated from the regular type cabs. This test is similar to SAE J334 but special requirements for cabs are spelled out.

27.	J389	Universal Symbols for Operator Controls on Agricultural and Light Industrial Equipment	1969

This standard establishes 58 symbols concerned with agricultural tractors and machinery for the purpose of providing a symbolic language for operator controls so that no matter what the language of the operator be, he may easily identify the various operator controls for proper and safe operation of the vehicle.

28.	J952b	Sound Levels for Engine Power Equipment	1966

This standard establishes the maximum sound levels and test procedures for construction, agricultural and industrial tractors.

NATIONAL SAFETY COUNCIL
CHICAGO

OFFICE OF THE PRESIDENT

September 29, 1970

Mr. Douglas W. Toms, Director
National Highway Safety Bureau
U. S. Department of Transportation
Washington, D. C. 20591

Dear Mr. Toms:

In response to your request regarding information on agricultural tractor accidents and reporting procedures, we are pleased to enclose a paper to this end developed by our Farm Department and the NSC study entitled, "Product Accident Reporting Feasibility Study."

We hope you will find this information, plus the documents previously sent to your staff, helpful in your deliberations.

Sincerely,

Howard Pyle

Howard Pyle

HP:jhl
Enc.

National Safety Council   September, 1970

Information Concerning Agricultural Tractor Accidents, Deaths and Injuries

State of the Art

Continuous efforts have been made to obtain information, statistics or the circumstances on tractor accidents for the past 25 years or more. These efforts have been successful in indicating the existence of a serious accident problem and have revealed significant details of the circumstances but an accurate profile of the problem, nationally, has been extremely elusive.

In most states and at the national level, tractor fatalities, recorded on death certificates, are tabulated in a farm machinery category and not itemized separately. Even if tabulated separately, which a few states do, the information on the death certificate is of little value in determining how the accident really happened or what could be done to prevent future such happenings.

Some farmers have purchased workmen's compensation and/or employer's legal liability insurance. However, claims arising out of these kinds of coverages are not nationally co-ordinated and are not compatible from state to state. Thus, insurance claim data would not be a reliable source of information to accomplish the objectives sought.

Enclosed with this paper is a recent study conducted by the National Safety Council entitled, "Product Accident Reporting Feasibility Study". This study was supplied to the National Commission on Product Safety and was included in its report to Congress. We direct your attention particularly to pages 1-3, 1-14 through 1-22. Page 1-23 is a quick recap of sources of product safety information examined.

A system, similar to the recommendations of this NSC study, is now in place and working. If expanded it would, at a modest cost, achieve your objective of information sophisticated enough to make intelligent decisions regarding tractor accidents.

In 1967, Ohio State University conducted a farm accident study on a random stratified sample basis using supervised volunteers. Prior studies of a similar nature were conducted in 1957 and 1962. In 1968, Michigan State University conducted an accident study based on the Ohio State procedures. It was the first time that two states were able to compare their respective situations directly.

The National Safety Council, in co-operation with these two states, has developed and refined a step-by-step procedure that any state could use in conducting similar studies. Nine "starter" grants of $2,000 were authorized by NSC for states which would conduct such studies using the NSC procedure. To date, three states, New York, Ohio and Michigan have completed surveys and six states are in progress. All will be completed by 1972.

The NSC standardized study offers the following advantages:

1. It uses existing structured organizations (usually the state extension service based at land-grant universities).
2. It uses existing expertise (the state extension structure embodies computer services, statisticians, organization personnel and volunteers).
3. It uses trained volunteers at the local level supervised by professionals.
4. It obtains information which is statistically sound and acceptable.
5. It is inexpensive when compared with other methods. (Estimate from

Ohio would indicate a cost of over $100,000 if professional inputs and volunteers would have been paid, mileage, etc. A grant of $1,000 was all the outside money obtained.)

6. It works. Having been completed in three states it is now past the realm of theory.
7. The data can be pooled at NSC, ultimately providing a 25 to 30 thousand farm sample representing approximately a million farms in the nine states sampled.
8. The information can be compared directly between states or against the national total.
9. It delineates top priority accident problems to help us make more effective use of the limited resources available.
10. It provides motivation for approximately 300 to 500 persons throughout each state who may be interested in instituting countermeasures to reduce the accident problem.
11. It adds the new dimension of bi-level reporting. More in-depth information will be in hand on specific types of accidents. This information about man, machine and environment can be subjected to advanced problem-solving techniques and specific countermeasures developed.
12. It points the way intelligently toward possible third level professional research. (Epidemiological studies, etc.)

National Standard for Agricultural Tractor Accident Records

On the strength of the Council's success with its standardized accident reporting procedure and system we feel it is unnecessary to develop another.

It would be unrealistic to believe that all tractor accidents could be found, particularly those that did not result in an injury, and the cost of examining each one individually would be prohibitive. Random stratified sampling techniques are well recognized and an acceptable means of gathering basic data consisting of frequency and severity of accidents. Coupled with bi-level reporting the system can generate more specific information plus an appreciation of the accident potential of the tractors, compared with other types of accidents on the farm and highway.

Ideally, the country could be divided into ten regions of five states, with one state conducting the NSC standardized accident study each year on a rotating basis. The plan would yield a continuing source of new data on all types of farm accidents and not be limited to tractor accidents. This data would provide a means to compare and rank various types of accidents as to deaths, injuries and costs. Accident trends could be revealed. To varying degrees the effectiveness of countermeasures could be judged by comparing accident experience before and after they were employed. Ineffective measures could be scrapped and new ones applied to bring about desired accident reductions. The potential for computer searches and in-depth analysis of specific types of accidents would be limitless.

We would strongly recommend not only the continuation but the expansion of the NSC program, since it is achieving the objective of adequate information to make intelligent judgments and at a cost well below that required to establish an entirely new system.

Cost/Benefit

It would appear that the cost of obtaining tractor accident data is reasonably predictable. However, it is extremely difficult to predict the benefits which might be derived without knowing how the survey information will be used.

One benefit of the NSC procedure would be a means of observing trends in tractor accident experience based on first level information. This would permit the establishment of priorities and the allocation of resources.

A second benefit would be derived from the bi-level reports which offers the information necessary to develop countermeasures (education, legislation, design changes, etc.) to incorporate into the man-machine system to prevent accidents or to mitigate injury.

NOTE: (ADDED BY THE NATIONAL HIGHWAY SAFETY BUREAU)

The report Product Accident Reporting Feasibility Study, referenced on page one of this paper, is not included in this report. However, the Council study was reviewed thoroughly by the National Highway Safety Bureau study group which prepared this report on agricultural tractor accidents. Inquiries should be directed to the Council's offices at 425 North Michigan Avenue, Chicago, Illinois 60611.

"TRAINING FOR OPERATORS OF AGRICULTURAL TRACTORS AND OTHERS WHO WORK IN ENVIRONMENTS WHERE SUCH TRACTORS ARE USED"

by

Dr. F. R. Willsey
Extension Safety Specialist
Department of Agricultural Engineering
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Lafayette, Indiana

September 25, 1970

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"TRAINING FOR OPERATORS OF AGRICULTURAL TRACTORS AND OTHERS WHO WORK IN ENVIRONMENTS WHERE SUCH TRACTORS ARE USED"

CURRENT STATE OF THE ART

The training for operators of agricultural tractors varies greatly in both quantity and quality. In some localities, there is no organized training program available. In a nearby community, there may be an opportunity to chose between two training programs. Almost invariably, such programs are made available to boys in the ten to twenty year age range.

Individual instruction probably varies almost as much as the more formalized training programs. In most of these cases, the father is the instructor and the young son is the pupil. In some cases, there may actually be no specific training. On the other hand, such training may be quite thorough and extensive. Safety instruction may range from a simple and ineffective warning "be careful" to a well conceived effort at safety education.

Traditionally, participation in training programs has been on a voluntary basis. There have been some incentives which have tended to encourage participation. For example, completion of the 4-H tractor program has provided the 4-H participant with another completed 4-H project to add to his record of 4-H achievements. It might have also provided him with an opportunity to win further recognition by participating in 4-H tractor operator's contest. More recently, completion of certain parts of the 4-H tractor program has been required before persons in the 14 and 15 year old age group can legally operate a tractor except "when employed by his parent or person standing in place of his parent on a farm owned or operated such parent or person." Those under 14 cannot legally qualify for such work with other employers even if they have completed such training. This relatively recent ruling concerning the employment of children below the age of 16 in "agricultural occupations deemed particularly hazardous" seems to have had varing effects upon the enrollment in the 4-H tractor program. In some states, rather sharp increases in 4-H tractor enrollment appear to have resulted from this ruling. In other states, little or no increase has been noted.

Vocational agricultural instructors are now authorized to certify students by using a plan very similar to the one available to the Extension Service for certifying 4-H club members. Previously, only those Vo-Ag departments that qualified for a special "cooperative vocational educational program in agriculture" could place students in certain jobs "necessarily incidental to his training;" if the work was "intermittent, for short periods of time, and under direct and close supervision," etc. The new option available to vocational agriculture has not been in operation long enough to assess its influence as to the number of tractor operators that might be trained or the effectiveness of the training.

Training of adults for the operation of agricultural tractors has been tried in only rare and isolated cases. The fact such training has not spread seems to indicate that it is not in great demand.

It seems rather apparent that the scope and quality of training programs is very favorably influenced by the presence of full-time safety specialists on the Cooperative Extension Service Staffs of the Land Grant Colleges and Universities. They have provided much of the data upon which safety literature is based. They have prepared or inspired many visual aids and ideas for demonstrations. They often provide instructional help as guest speakers, leader trainers, etc. Unfortunately, only a few states have seen fit to hire a full-time safety specialist.

It seems safe to assume that no specific training programs have been designed for others who work in environments where agricultural tractors are used. However, training programs designed for tractor operators usually contain warnings to the operator concerning extra riders and other situations involving persons who might be in the environmental area.

DEVELOPMENT AND EFFECTIVENESS OF CURRENT PROGRAMS

Most of the material now being used to train operators of agricultural tractors has evolved from the original 4-H tractor training material. There was much interest in this program even before 1950 and the materials in the course were reviewed from time to time and changes were made in attempt to meet existing needs. A rather extensive modification of the educational material for the 4-H tractor program was made in 1963.

The 4-H tractor program has been used as the basis for qualifying 14 and 15 year olds for exemptions from the U.S. Department of Labor regulation concerning employment as operators of agricultural tractors and certain other machinery.

To a large extent, the same basic literature is being proposed for use by teachers of vocational agriculture as a training aid for their students. For example, the same Tractor Operator's Contest Course is generally recommended to test driving ability of both 4-H and vO-ag students. While this course may differ in detail in the various localities, the basic principles are generally the same.

Although some sort of contest courses usually are used to check the student's ability to operate the tractor, most training programs do not allow for supervised practice in actual tractor operation. While most students have extensive opportunity to practice operating tractors, it appears that their safety training might be more effective if their driving habits were reviewed in actual or simulated operating situations at the time they are receiving safety instruction. Apparently with this thought in mind, some training programs have been designed to include such supervision.

If any scientific analysis of the relative values of various levels and types of training programs has been made, the results have not been widely publicized. On the other hand, it seems rather obvious that the appraisal of such effectiveness would be very difficult. In the meantime, it seems that current programs have been developed primarily upon the basis of what appears to be useful and practical in view of existing needs and financial support.

CONTRIBUTIONS OF GOVERNMENT, INDUSTRY, AND OTHER GROUPS

Training programs have been supported by various agencies. The extension service of the U.S. Department of Agriculture at the Federal, state, and local levels has assumed much of the leadership role in cooperation with the National 4-H Service Committee. As in most extension service programs, voluntary leaders have made a major contribution at the local level. The local agricultural implement dealers have contributed in terms of space and materials used in the meetings. They have also provided instructional help in many situations. State associations of implement dealers have contributed awards and have provided leaders for various aspects of the program. In several states, the Standard Oil Company, now the Standard Division of the American Oil Company, has provided financial assistance and qualified leadership.

Several years ago, the American Petroleum Institute made a motion picture, Farm Tractor Safety and a later version Farm Tractor Safety-A Family Affair. These were the results of the efforts of one man who has since retired.

While the approach to the program has varied from state to state and within the states, it is apparent that many organizations and individuals have contributed to bringing about whatever success has been achieved by training programs for operators of agriculture tractors. It is difficult to say to what extent the changes in the program over a period of years can be attributed to agricultural changes in general and how much should be assigned to changes in leadership personnel, industrial support, and other related factors. For example, farms have become larger. There are fewer farm boys than was the case a few years ago. Dealerships for agricultural equipment are now larger and fewer than they have been in the immediate past. Farmers and their sons appear to be busier with many activities and may find it more difficult to justify time spent in tractor training programs.

However, the most drastic change that is evident in some states is the decrease in financial support for the 4-H tractor program from industrial sources. For example, in Indiana, the Standard Oil Company contributed $3,150 towards the 4-H tractor program in 1959. In 1960, the contribution was the same. In 1961, it dropped slightly to $3,000. The contribution was $2,250 in 1962, but suddenly dropped to $190 in 1963 and remained at that level in 1964. At the present time, the company is contributing only $100 per year.

Leadership training has been the biggest loser. During the peak period of financial contribution, there was a 3-day training period for county volunteer leaders. This was held at Purdue University. At the same time, a shorter refresher course was for experienced leaders. This session was looked forward to by many and appeared to be a very stimulating force in the total program.

Enrollment in the Indiana Program reached its peak in 1953 with 4,106 completions. The figure was 3,027 in 1962, and 1969, 2,312. As has been inferred earlier, it is difficult to say how much, if any, of this change in enrollment might be attributed to the decreased financial support. Obviously, there are other factors involved.

It seems apparent that the Federal Government has demanded additional training in the form of a work order, but it has not provided additional help in terms of financial support, leadership, and teaching aids.

SOME TRAINING PROBLEMS AND RECOMMENDATIONS

There are some problems associated with the training program. No doubt, these vary considerably from state to state and from one organization to another.

One problem is simply that of public awareness. In spite of all the publicity that has been given to the availability of training programs and a necessity for certain training for compliance with the hazardous work order, many people apparently are unaware of the work order and still others are not familiar with the training provisions which can qualify 14 and 15 year olds for exemptions. Part of the difficulty may be that people often have difficulty associating this program with their needs. For example, a boy may live in small town and neither he or his parents have even considered the possibility that he might want to work on one or more neighboring farms. Therefore, they pay no attention to an announcement which, at the moment, has no meaning to them. Even farm families may assume that their son will never need to fulfill certain training requirements in order to legally operate a tractor on a farm other than their own. So although these people may actually see the article in the paper or hear it on radio they may not comprehend its meaning or bother about further investigation.

In some cases, interested parties may learn that a suitable training program is not available in their county. More commonly, they may find that they have waited too long to meet all necessary requirements by the time employment is available. For example, in the 4-H tractor program, safety is scattered over three years of the training program. This means that unless special sessions are held, training needs must be anticipated more than two years in advance. The course outlined for the 4-H tractor program is designed with safety units placed appropriately throughout the course and special safety emphasis in the first year of the program. It doesn't seem proper to restructure the basic program to accomodate the relatively few who would benefit by having all the safety requirements condensed into one year. A lack of adequate leadership provides a further complication to setting up special programs although this appears to be the only practical way to meet this problem squarely. However, Iowa and Kansas are examples of states where concentrated training courses have been held with apparent success.

Another training problem concerns the practical driving test. The driving course that is recommended requires some time and effort to set up. This may not be practical to do for a relatively few trainees. While the course would seem to measure several aspects of an operator's ability to handle the tractor safely, it seems doubtful that such a relationship has been established.

As far as the driver's attitude is concerned, it seems this would be as difficult to measure for tractor operators as for operators of automobiles. Personal observations on the part of the instructor, the parent and the employer might be more valuable in measuring this characteristic than would most formal testing devices.

The need for well trained leadership at both the professional and volunteer levels is one of the problems facing state leaders of 4-H tractor programs. Fortunately much of the instructional material is well prepared and if followed, most leaders can do an adequate job. However, reading of printed instructions is not a complete substitute for in-person training of leaders.

COMMENTS CONCERNING LICENSING OF TRACTOR OPERATORS

It seems reasonable and proper to require that the operator of a tractor or a self-propelled machine on our highways should have a license to drive an automobile in the state in which he lives. It does not seem practical to require special licensing of operators for each and every type of farm machine. Neither does it appear to be reasonable to require operators to have licenses to operate machinery on their own farms.

SOME INNOVATIVE APPROACHES

Attached are three exhibits provided by Dr. Richard G. Pfister, Extension Safety Engineer, Michigan State University. They concern a cooperative project with Deere & Company to develop a universal training program for tractor operations.

Exhibit A - Describes nature and design of the program.

Exhibit B - Presents an application of this course presented in Western Michigan during the spring, 1970.

Exhibit C - Presents one of the 76 lessons being developed.

Also, Dr. J. B. Liljedahl, Professor of Agricultural Engineering, Purdue University, is proposing that the Departments of Agricultural Engineering and Agricultural Education at Purdue cooperate on a research project with the following objectives:

1. To develop an entirely new training program for junior high and high school age tractor drivers with emphasis on safety.
2. To point out the emergency conditions which exist with tractors which are a potential hazard to the driver or others nearby.

3. For each hazardous condition develop a generalized emergency procedure which would greatly reduce or eliminate the risk to human life. For example: (a) In most (possibly all) cases when a tractor begins to overturn rearwards, simply disengaging the clutch will prevent the overturn if the clutch is disengaged in time. (b) When using a frontloader on the tractor and the tractor begins to overturn sideways, the potential accident could usually be prevented if the loader was dropped to the ground. (c) When a tractor begins to overturn sideways because of a ditch or a bump, a slope or a turn (or some combination) the potential overturn can be prevented by quickly turning the tractor in the direction of overturn.
4. Develop a tractor ride simulator which is especially designed to train young tractor drivers in emergency conditions.

The idea for this proposed research came from an analysis of Indiana tractor overturning accidents which indicated that relatively few tractor operators reacted properly when overturning situations developed.

The extent of the proposed research will depend upon the availability of funds.

EXHIBIT A

RURAL MANPOWER CENTER
MICHIGAN STATE UNIVERSITY • EAST LANSING, MICHIGAN 48823
FORESTRY BUILDING
Reply: 222 Agricultural Engineering
Michigan State University
East Lansing, MI 48823

PROGRAM: A BASIC TRACTOR OPERATOR'S TRAINING PROGRAM FOR PERSONS WITH A LOW EDUCATIONAL LEVEL.

CURRENT STATE OF THE ART:

As they exist today, most training programs do not meet the needs of the trainee or the occupation they hope to enter. In both the U.S. and the developing countries well-intended but poorly-planned, conceived, and implemented programs of training leave the trainee frustrated; and the employer infuriated. A different approach to training the disadvantaged must be taken if past failures are to be rectified and new hope be given to aspiring but woefully inadequately prepared workers who desire a better life.

As a result of the inconsistencies and apparent need for a different approach, the Agricultural Engineering Department at Michigan State University undertook a cooperative project with John Deere to develop a universal tractor training program that could be used anyplace in the world, especially under cross-cultural conditions. The Basic Tractor Operator's Course that was developed is the first of a series of courses to upgrade and inculcate saleable skills in individuals for human resource development.

IDENTIFICATION OF BASES ESSENTIAL TO EFFECTIVE TRAINING PROGRAMS:

The MSU/JD Basic Tractor Operator's Training Program is founded upon four principle concepts:

a. A Systems Engineering approach to the problems of training (PERT and CPM)* including measurement of input and continuous evaluation of output.

b. A Modified Structurer Learning and Training Environment (MSLATE) based on clearly defined and measurable behaviorable objectives.

c. The design of a program based on the needs of the trainees and emphasizing individualized instruction.

d. A definite program to train the instructors how to use the developed course and how to teach the trainees of low educational level.

In order to develop a training course based on these criterion, a tremendous amount of work must be done by the developers. This is probably the main reason that very few well-planned and throughly prepared courses have been prepared. If it takes a lot of work to develop a course for university level students who can read and write, how much more must it take to train someone where every situation and skill must be throughly and clearly presented without the benefit of self instruction on the part of the trainees? Then mix in a little cross-culture where the trainee speaks and thinks in a different language, and the job of training is much more exacting and challenging.

A special tractor training program was designed and tested for persons with low educational levels. Using the latest techniques of programed learning, the program was prepared stressing the involvement of each trainee in a "hands on" learning approach. To measure the effectiveness of the training program, evaluation was carried out before, during, and after instruction.

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*Program Evaluation Review Technique and Critical Path Method

Evaluation is an important technique in determining the effectiveness of a training program. They typical pencil and paper test is inadequate because it fails to measure the achievements of trainees who cannot read or write beyond the fifth grade level. Therefore, the MSU/JD Basic Tractor Operator's Training Program utilizes performance tests to measure trainees attainment against a set of standards based on the desired objectives. These performance tests certify the degree to which the trainees are qualified as tractor operators.

CONTRIBUTORS TO THE MICHIGAN STATE UNIVERSITY/JOHN DEERE TRACTOR OPERATOR'S TRAINING PROGRAM:

Training Program Development:

A Cooperative Project Between
MICHIGAN STATE UNIVERSITY
Agricultural Engineering Department
East Lansing, Michigan
and
DEERE & COMPANY
Moline, Illinois
by
Mr. C. K. Kline
Mr. C. G. Bolton
Dr. C. J. Mackson, Project Leader

Training Facilities and Instruction:

GRAND RAPIDS JUNIOR COLLEGE
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Coordinating the Cooperative Agencies and General Curriculum Contact:

MICHIGAN STATE UNIVERSITY
Howard J. Doss
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Frank Klackle
District Extension Horticultural Agent

Dr. Frank Bobbitt
Vocational Education Specialist
College of Education/Rural Manpower Center

Trainee Stipend and Coordination:

UNITED MIGRANTS FOR OPPORTUNITY, INC.

Mr. James R. Shrift
Executive Director
Mr. Pleasant, Michigan

Mr. Ray Gutierrez
Grand Rapids Area Coordinator

Training Program Funding:

STATE OF MICHIGAN

Mr. Richard Karelse
Consultant Agr. Edu.
Department of Education
Division of Vocational Edu.

Job Placement of Trainees:

UNITED MIGRANTS FOR OPPORTUNITY, INC.

GRAND RAPIDS JUNIOR COLLEGE

MICHIGAN EMPLOYMENT SECURITY COMMISSION

IDENTIFICATION OF TRAINING PROBELMS AND THEIR SOLUTION:

During the preliminary testing of the Basic Tractor Operator's Course, it became apparent that all instructors, regardless of their previous training or teaching experience, must be given the opportunity to take part in an Instructors Training Program. As the machine is no better than its operator, the best training course is dependent upon the skill and qualification of its instructors. To develop the proper skills and attidues, the instructor working with disadvantaged or low-educated level trainees, must be trained in the art and techniques of teaching sophisticated skills to unsophisticated people. He has to be able to view the training from their frame of reference and understand their way of thinking. For example, preventative maintenance meaning absolutely nothing to the African, Asian, rural, or getto disadvantaged who never thinks in terms of fixing anything until after it is broken. Hence, the tractor "just spoiled" and the driver accepts no personal responsibility for what happened because, in his world, things just happen that way and you accept it and shrug your shoulders. Developing positive and proper attitudes is one of the most difficult tasks in training disadvantaged because derogatory attitudes must often be changed before they can be replaced by desirable ones.

LICENSING OF TRACTOR DRIVERS:

If tractor operators are to be licensed, the training program developed by Michigan State University and John Deere has established three grades or proficiency levels of tractor operators. By using the training programs developed, the agency that issues the tractor operators license could set the minimum grade level necessary to obtain an operators license. Performance criteria and testing procedures to obtain these grade levels are outlined in the MSU/JD Training Program. The three grade levels and their respective titles are listed as follows:

Grade I: Basic Tractor Operator

Grade II: Advanced Tractor Operator

Grade III: Fully Qualified Tractor Operator

Howard J. Doss
Agricultural Mechanization Specialist
Agricultural Engineering Department
Michigan State University
September, 1970

HJD/kd

EXHIBIT B

RURAL MANPOWER CENTER
MICHIGAN STATE UNIVERSITY • EAST LANSING, MICHIGAN 48823
FORESTRY BUILDING

STRUCTURED EDUCATION IN AGRICULTURE

A Basic Course in Agricultural Machinery for Michigan Fruit Farms

Howard J. Doss
Agricultural Mechanization Specialist

A-210 / A-211

STRUCTURED EDUCATION IN AGRICULTURE

A Basic Course in Agricultural Machinery for Michigan Fruit Farms

PURPOSE: To provide a fundamental training course in modern Agriculture for a group of ex-migrant workers. The course will allow persons with a low educational level to become experienced, basic Agricultural Tractor operators. They will also have basic knowledge of fruit farming operations.

Farmers, and more importantly their employees, require special training to learn how to operate modern farm machinery effectively and safely, to adjust it properly and to keep it in serviceable condition. Many people have limited association with mechanical devices. These people must be taught the basic mechanics of machine systems, the need for lubrication, service and intelligent operation. Without adequate training, machinery operators cannot be expected to do good work with machines or to carry out practices which prolong machine life or protect them from abuse and damage.

The purpose of this training program for basic tractor and equipment operators is to convert unskilled labor into skilled workers and technicians. As a result of this training, these people will hopefully be in a better position to provide themselves with a living income and be a part of today's productive society.

Probably the greatest problem in intelligently utilizing and applying farm machinery is adequately educating the operator. This means not only imparting certain skills to him, but developing in him a proper attitude toward work and responsibility. He must have some understanding of why he must do certain things and why they must be done in a certain way. This course attempts to upgrade the operator's skill and knowledge level.

The bulk of the six to eight week course will be on basic tractor operation. A basic tractor operator is one who after training and sufficient practical experience can operate the tractor skillfully, can use it in conjunction with selected tools and implements in specific farming operations and can properly perform specified daily maintenance and preventative maintenance services. A tractor operator shall be able to use the tractor and attachments safely without danger to himself or others. He shall be able to operate them without subjecting them to abuse or damage or otherwise causing unnecessary wear and tear beyond normal operating rates. He shall be familiar with and have a basic understanding of common farming operations and know the important aspects of rational and economical tractor and implement use. He should realize that good preventive maintenance care of the tractor and implement is his responsibility. He shall have pride in his work and job and value his skill as a qualified operator. He shall constantly seek to improve his knowledge and skill and have the conviction that a better understanding of how a tractor and implement works is necessary for its proper operation and maintenance. He shall have a positive attitude toward his work, be conscientious in performing all tasks and be dependable in carrying out instructions. The operator will be able to take some responsibility on himself. He shall realize that if the tractor breaks down or is damaged through lack of care or abuse, that he, as the operator, is to blame.

The suggested outline for the BASIC TRACTOR OPERATORS' TRAINING COURSE is as follows:

I. The course will be divided into two subject areas. The first area will be a basic tractor operators' training course. The second area will involve a special orientation to Michigan fruit farming operations.

   A. Getting Acquainted with the Tractor

      1. Orientation
      2. Tractor Nomenclature
      3. Principles of Engine Operation
      4. Internal Combustion Engines
      5. Principles of Tractor Operation
      6. Preliminary Driving

    7. Power Transmission
    8. Common Hand Tools

B. Getting the Tractor Ready for Work--Prestarting Checks

    1. Need for Care and Maintenance
    2. Daily Maintenance Services
    3. The Fuel System
    4. Checking the Fuel Guage and Adding Fuel
    5. Checking and cleaning the Sediment Bowl
    6. The Air System
    7. Servicing the Precleaner
    8. Servicing the Oil Bath Air Cleaner
    9. Servicing the Dry Filter Type Air Cleaner
    10. The Engine Lubrication System
    11. Servicing the Crankcase Oil
    12. Greasing the Tractor
    13. The Cooling System
    14. Servicing the Cooling System
    15. The Electrical and Wheel Systems
    16. Servicing the Battery
    17. Checking Tires and Wheels
    18. The Daily Maintenance System
    19. Keeping Daily Maintenance Records

C. Starting and Warming the Engine

    1. General Procedure and Safety
    2. Mounting the Tractor
    3. Adjusting the Seat
    4. Using the Clutch
    5. Setting Range and Gear Controls
    6. Setting the Hand Throttle
    7. Starting and Warming the Engine
    8. Reading the Alternator Light
    9. Reading the Oil Pressure Light
    10. Reading the Water Temperature Gauge
    11. Reading the RPM-MPH Indicator

D. Operating and Maneuvering the Tractor without Equipment

    1. General Safety
    2. Using the Hand and Foot Throttles
    3. Selecting the gear and range
    4. Using the Steering Wheel and Brakes

E. Maneuvering the Tractor

    1. Starting the Tractor Moving
    2. Setting the Throttle to Vary Engine Speed
    3. Shifting Gears and Range with the Clutch
    4. Steering the Tractor

5. Reading the Instrument Panel under Operation
6. Braking Slow-Moving Tractor to Stop and Steer
7. Slowing and Stopping Fast-Moving Tractor
8. Stopping Engine and Parking the Tractor

F. Managing the Tractor--Using Good Judgment

1. Operating the Tractor Under Difficult Conditions
2. Selecting Gears to Avoid Overloading
3. Using the Differential Lock and Power Shift
4. Breaking in a New Tractor
5. Tractor Management, Records, Costs and Parts
6. Wheel Slip and Traction
7. Traffic Signs and Hand Signals
8. Traffic Rules and Regulations

G. Using the Tractor as a Power Source

1. The Basic Power Systems
2. Adjusting and Hitching to the Drawbar
3. Using the 3-Point Hitch with Rockshaft, Load and Depth Control
4. Attaching and Detaching 3-Point Hitch Implements
5. Hitching and Using the Remote Hydraulic Cylinder
6. Types of 2-Wheel Trailers and Preservice
7. Loading and Maintenance
8. Pulling 2-Wheel Trailers and Implements
9. Backing 2-Wheel Trailers
10. Types of 4-Wheel Wagons
11. Loading and Maintenance
12. Pulling 4-Wheel Wagons
13. Backing 4-Wheel Wagons

H. Safety Factors

1. Selection and Safe Storage and Handling of Fuels and Lubricants
2. Guidelines for Human Safety
3. Guidelines for Tractor Safety

I. Using the Tractor in Productive Farming Operations

1. Plowing-disc
2. Plowing-moldboard
3. Disc Harrowing
4. Mowing
5. Power Spraying
6. Other

II. SPECIAL ORIENTATION TO MICHIGAN FRUIT FARMING OPERATIONS

A. This orientation will be of a short course or workshop nature covering such topics as:

1. Operation and care of sprayers
2. Harvesting and pruning equipment
3. Spray chemical usage and safety
4. Cultural Practices
5. Fertilizer Use and application
6. Fuel and chemical precautions

HJD/jt
3/12/70

EXHIBIT C

RURAL MANPOWER CENTER
MICHIGAN STATE UNIVERSITY • EAST LANSING, MICHIGAN 48823
FORESTRY BUILDING

STRUCTURED EDUCATION IN AGRICULTURE

A Sample Lesson

from

TRACTOR OPERATOR'S TRAINING PROGRAM
BASIC COURSE - GRADE I
INSTRUCTOR'S MANUAL

A Cooperative Project Between
MICHIGAN STATE UNIVERSITY
Agricultural Engineering Department
East Lansing, Michigan
and
DEERE & COMPANY
Moline, Illinois

by

Mr. C. K. Kline
Mr. C. G. Bolton
Dr. C. J. Mackson, Project Leader

A 218/ A-219

NOTE: ALL 76 LESSONS CONTAIN SAFETY PRACTICES
CONCERNING SAFE TRACTOR OPERATION
H. Doss

LESSON C-1
GENERAL PROCEDURE AND SAFETY

Behavioral Objectives	Information for the Trainees	Instructional Methods
The tractor operator:		
a. will follow a definite procedure in starting the tractor.	After the prestarting checks have been completed and the needed service performed, the operator is ready to actually start the engine and get the tractor ready for the day's work. There is a definite procedure for starting and checking out the diesel engine before it is put to work (see Lesson C-5). It is slightly different for a gasoline engine so the operator must learn the correct way. Just as the pilot of a jet airplane must check all controls and follows a precise pattern in preparing the jet airplane to fly, so must the operator of a modern farm tractor follow a systematic procedure before driving off to work.	Show slide of cockpit of jet plane. While modern farm tractor is not as complicated as a jet airplane, it is just as scientifically made and requires a definite procedure to operate it properly.
b. is responsible for caring for his tractor.	Normally, only one operator is given the responsibility for caring for and maintaining a machine like a tractor. Other people may help him but he alone is held directly responsible for what happens to the tractor. Generally this operator will be assigned to a specific tractor and will do all things	Generally the use of one driver for one tractor encourages the acceptance of responsibility.

Behavioral Objectives	Information for the Trainees	Instructional Methods
	related to its basic care and use. Sometimes an assistant driver is selected to work with the skilled operator as a helper. This is a good way for an experienced, qualified operator to help train a new driver. Then in case of an emergency or sickness, the assistant driver can take over the care and operation of the tractor.	
c. will properly warm up the tractor engine before starting work.	The diesel or gasoline tractor has a rugged, powerful engine that requires a minimum of care. It must now, however, be driven and put under load until after the engine is warmed up. If the engine is forced to work while it is cold, extensive damage may be done to it that requires expensive repairs. During the warm-up period the operator has a chance to observe the engine and to check the various gauges for proper operation. Since all metals expand or get slightly larger when hot, the engine parts are made to give the best fit when operating at the designed temperature. When cold, the parts fit loosely and are not capable of taking the heavy stresses imposed on the engine under heavy load.	Compare metal to rice. Just as rice swells and takes up more space when it is heated (cooked), so does metal expand when heated. Parts that get **very** hot, therefore, must be fitted loosely when cold.
d. study each control and learn its function and setting.	During the preliminary driving exercise you used the basic controls without studying them to manipulate the tractor. Today you will learn more about each control and the the various settings for them. The first step is to adjust the seat to fit your body so	While all controls have variable settings, there are certain settings at which the tractor works best to perform specific tasks.

Behavioral Objectives	Information for the Trainees	Instructional Methods
	you can reach all controls easily and effortlessly. Then you will set major controls to prepare the tractor for starting. The throttle must be set to operate the engine at a fast idle which is neither fast nor slow. If the engine runs too slow it will not warm up properly; and it may be seriously damaged if it overspeeds. All load must be disconnected from the engine to permit it to start with the least strain. For safety you must make sure the engine is not connected to the wheels so that the tractor will not start moving when the engine starts. This is done by placing the transmission shifting levers in the correct position.	
e. study each gauge and instrument and learn its meaning and use.	To protect the engine from possible damage should it not have the proper amoung of oil and water, special "red trouble lights" will light up after the engine starts to catch the operator's eye and warn him of possible danger. The operator must observe these lights periodically to ascertain that the engine is operating normally. After much practice the operator will go through these steps and check each gauge almost automatically. But for now all trainees must pay special attention to the following: 1. alternator light 2. oil pressure light 3. water temperature gauge 4. RPM gauge	Compare the red traffic signal light to the engine warning light. In addition to controls the tractor is equipped with special gauges and signal lights that tell the operator when the engine is working properly; also when something is wrong and the operator when the engine is working properly; also when something is wrong and the operator must stop the tractor and engine.

	Behavioral Objectives	Information for the Trainees	Instructional Methods
		So if you do something too quickly without thinking, you may not have time to stop the action. As beginning operators, therefore, you must be very safety minded and think through each step as it is performed.	
f.	will develop a safety consciousness and pause to think before he acts.	One thing to always keep in mind is safety. For your protection the tractors and other people who may be around, think, live, and act safety.	Tractor operators must practice safety to live safely.
g.	will practice good housekeeping habits.	If you spill some oil, grease or fuel on the tractor or on the floor, stop and clean it up before someone slips and hurts himself or before it messes things up and gets tracked all over the place. Spilled oil and fuel also creates a fire hazard.	
h.	will not smoke when servicing the tractor.	Never smoke while you are servicing the tractor. There is always danger of fire and an accidental dropping of a lighted match or cigarette can ignite fuel, oil, rags or other material. The fumes from the battery are also combustible and can cause a fire. Do not smoke while handling fuel of any kind or refueling the tractor. Remember that fumes are heavier than air and collect on the floor and in low places. If fuel is spilled in a closed building, open the doors and windows to ventilate the area.	Capture fumes from diesel fuel or gasoline in an inverted glass. Then turn glass on its side and light the fumes to show the concentrated vapor is heavy and dangerous.

	Behavioral Objectives	Information for the Trainees	Instructional Methods
i.	will not run the engine inside a closed building.	Never operate the tractor engine inside a building with all the doors and windows closed. Preferably a special pipe should be connected to the end of the exhaust pipe with the opposite end discharging outdoors. Exhaust gases from an internal combustion engine contain a poisoness gas, CO_2, which you cannot see or smell. You must be careful not to take chances by running an engine indoors and exposing yourself and others to this hazard.	Demonstrate that a rat or mouse is quickly affected by exhaust fumes.
j.	will block tractor so it cannot roll or move on uneven ground or when jacked up.	Always make sure the tractor is blocked so it cannot roll while you are working on it. Try to park or stop it on level ground. Set the brake (if the tractor is so equipped) and place the transmission in Park, position "P." If any wheel is jacked up off the ground, block the other wheels so the tractor cannot move off the jack accidentally or slip.	EMPHASIZE never take chances. Always block the wheels. Show how to block.
k.	will avoid hot parts which can cause serious burns.	Be careful of getting burned on hot parts of the engine. When the tractor is used the engine gets very hot and particularly the exhaust pipe. Be careful not to touch it while the engine is running or immediately after it stops until it has a few minutes to cool down.	Touch tissue paper against hot manifold or exhaust pipe and muffler to show how it gets scorched or burns.
l.	will not work on tractor while it is running or moving.	Be cautious around ant moving parts of the engine or tractor. Never stick your hand in around the fan, the fan belt, or generator while the engine is running. Also be careful around the 3-point hitch, and never operate it while someone is standing on it. In general, never attempt to service the tractor while the engine is running or the tractor is moving.	Stick paper in running fan belt. Put stick in 3-point hitch where it can be cnapped or broken.

GENERAL PROCEDURE AND SAFETY
TRAINEE ACTIVITIES LESSON C-1

Preconditions	Instructions to Trainees	Checklist	Instructional Aids
		Did trainee respond:	
Tractor in lab	Must operator follow systematic procedure in starting tractor?	1. yes, but different for diesel engine or gas engine?	See Flow Chart, Lesson C-5
	Who is responsible for tractor care?	2. *regular operator for daily and weekly service?	Slide of smiling tractor with happy operator
	Why must engine be warmed up?	3. parts are loose when cold and must expand to fit properly before doing work?	Heat old bimetalic switch with match?
	Why are tractor signal lights like a traffic signal?	4. *tell operator when it is safe to run tractor, and when it is not safe?	Refer to driver education chart with traffic light
	What do you do if you spill oil or grease?	5. *wipe it up to prevent falls or fire hazard?	Show how foot can slip on step
	Why must operator not smoke when servicing tractor?	6. fuel and battery fumes are explosive?	Burn collected vapor fumes
	Can you run tractor in closed building?	7. *no, exhaust gases are poisoness?	Open doors

Preconditions	Instructions to Trainees	Checklist	Instructional Aids
	How do you block a tractor from moving?	8. put in Park position; block both front and back of wheels; block tractor up in 2 places?	Blocks for holding tractor
	Where can you get burned on a tractor?	9. on exhaust manifold, exhaust pipe and muffler and hot radiator?	Hot exhaust pipe, not radiator
	Can you adjust tractor while it is moving?	10. *no, you might fall, slip, or get run over?	Slide on safety or safety chart
	Should you work on the engine while it is running?	11. no, fan can cut hands and hydraulic hitch can crush a foot?	Tractor running to show danger

*Trainee must know all starred (*) items.

LESSON: GENERAL PROCEDURE AND SAFETY C-1
TRAINING EVALUATION NO. 27

Pretest ______ Post-test ______ Date ____________ Trainee ____________________________

Instructions to teacher and assistants: This pretest is to be given to trainees before they receive training to establish how much they already know about the subject. The instructor will identify each question by number, read it slowly in English, clarify its meaning in the trainee's native language, and explain the possible answers. Expected completion time is 15 minutes. NOTE: This same test will be given again as a post-test at the end of the day on which this lesson is completed.

Instructions to trainees: PRINT your name and the date at the top of this paper. Check either pretest or post-test. Listen carefully as the instructor reads the question or explains the exercise. Place an X in the space you believe to be the best answer. Raise your hand if you do not understand what to do.

	Don't Know	Not Important	True	False
1. The operator should follow a regular system to service the tractor.				
2. The mechanic is always responsible for maintaining the tractor.				
3. The diesel engine does not have to be warmed up before being put to work.				
4. The operator must watch the "red trouble lights" regularly to be sure the tractor is working properly.				
5. Vapor fumes from diesel fuel and gasoline are lighter than air and collect against the ceiling.				
6. A tractor may be operated in a garage with the doors and windows closed.				
7. When jacking the tractor off the ground the wheels should be blocked so it can't roll.				
8. All hot parts of the tractor are protected so the operator can't be burned.				
9. In general the tractor should be serviced while the engine is running.				
10. It is all right to smoke when working around the tractor in the barn or garage.				

Farm Tractor Safety Training

by

R. Paul Marvin

University of Minnesota

The Situation

The Honorable Neal Smith, in his report to congress on Wednesday September 17, 1969 stated that on the average three American farmers are killed by their tractors every day. He also stated that the number of accidents is increasing with no apparent activity that is likely to improve the situation in the near future unless some additional attention is given to the problem. I quote Mr. Smith. " What is now needed is an extra push to insure that safe farm equipment is standard farm equipment. To insure this result, increased farmer education programs must be combined with more technological advances by the farm machinery industries."[1] The focus of this paper is on the farmer education programs and the role of safety education in reducing tractor accidents.

The National Safety Council[2] queried 133 schools of engineering about the safety activity including curriculum in each of the institutions. The 108 replies (81.2% return) reported three out of five had some activity. Twenty-seven had no safety course offerings while 18 reported course offerings. Only three institutions offered more than a single course or lecture.

The limited activity at the college level which is indicated by this study would point to one area where more emphasis could be productive if in fact education for safety can reduce the number of accidents.

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[1] Congressional Record - Extension of Remarks. September 17, 1969

[2] Pyle, Howard - *Safety - Its Demands and Rewards*, ASAE Journal April 1968

The need to establish a data bank of tractor accident information and to evaluate the information in terms of effectiveness of safety education programs is of prime importance. Information is available on the number of tractor accidents from various sources within and between states but reporting has not been uniform for compilation of national figures. Very few if any of these reporting sources indicate training or safety education of accident victims.

Minnesota 4-H has conducted an organized tractor program for more than twenty years which includes service, maintenance and safety. This program has always been sponsored by the American Oil Foundation. Vocational agriculture instructors in the public schools have taught similar programs on an individual department basis. The high school program has reached about 2500 students per year for the past ten years. Both of these programs have integrated the safety teaching with service and maintenance.

In January of 1968 the U. S. Labor Department established some regulation which established definite restrictions for tractor operators and machinery operation. At that time the U. S. Extension Service 4-H training program was authorized for exemption certification. Since that date the 4-H certification program in Minnesota has involved about 1800 fourteen and fifteen year olds annually. The U. S. Office of Education received authorization for their program on February 6, 1970. The U. S. Office of Education program is being conducted in the secondary schools by the vocational agriculture departments.

Courses of study for Safe Tractor Operation and Safe Farm Machinery Operation were prepared in 1969 by members of the graduate class in Mechanized Agriculture at the University of Minnesota under the supervision of Professors Jack True and Forrest Bear. The course of study for Safe Tractor Operation has been printed and distributed to all of the vocational agriculture instructors in Minnesota. The course for Farm Machinery Operation will be distributed in the fall of 1970.

Current programs, 4-H and F.F.A. emphasize safety training but do not include the teaching of operator proficiency.

Bases for Current Programs and Assessment of Their Effectiveness

The present safety education programs are based on the original 4-H Tractor Program but the safety portion is no longer integrated with service and maintenance.

The program was effective for safety awareness as was evidenced in written examinations and by public demonstrations and exhibits. There was no operating proficiency included so contests and driving demonstrations are not valid means of assessment.

Accident reports will be the final indicator of effectiveness of these youth programs but as of September 1970 no accidents involving certified youngsters have been reported in Minnesota.

Contributions to the Training of Tractor Operators

The U. S. Extension Service with the sponsorship of the American Oil Foundation have been the basis for the major part of the safety education. Tractor and machinery manufacturers and dealers have been helpful in supplying equipment and volunteer teachers for many of the youth programs.

In Minnesota the University has recently increased its contribution through the Agricultural Education and Agricultural Engineering Departments by providing teaching materials and resource personnel for tractor safety education and the State Department of Education has assisted in dissemination of the material.

Problems and Recommendations

One of the limitations of the 4-H program has been the necessity to rely on volunteer help. Too often the instruction is not well organized or taught. The implementation of the vocational agriculture program with the supporting teaching materials prepared at the University should improve the instruction.

Present programs are operated for 14 and 15 year olds under the Department of Labor regulation. There is need for a training program to train tractor operators of any age.

The existing programs are not open to youngsters who cannot operate a tractor. Since operator skills are not taught, a non-farm youngster cannot learn to operate a tractor and become certified under the existing programs. Provision is made under the Department of Labor regulation for such training programs but few if any are in operation.

Data collection and research analysis of the effectiveness of safety education programs is badly needed. Teaching techniques for safety education require special consideration since the end result must result in attitudinal change coupled with proficient skill performance. The two are not normally found together as objectives for a course. We have little or no research evidence to indicate effectiveness of existing programs.

Safe tractor operation should include skill proficiency standards for certification. Operator proficiency is not a part of the courses now being conducted.

The above mentioned problems with the recommendations indicate the need for adequate funding for the schools that have the responsibility.

Licensing of Tractor Operators

General licensing of tractor operators does not seem feasible. Policing, testing of proficiency and training would all be difficult problems; furthermore, we do not know what the requirements should be for a safe operator. We have no evidence as to age, general education, physical ability, etc. to use as a basis for licensing.

There is empriical evidence to recommend that tractor operators on the highway should be required to hold a motor vehicle operators license or a certificate under the Department of Labor regulation. More evidence is needed to determine if this minimum is adequate.

The requirements for automobile drivers licence should include more emphasis on tractor and farm machinery on the highway. The general public driver does not know the rights of farm equipment on the highway. Many do not know the "slow vehicle" symbol. Fifty per cent of tractor accidents involve automobiles on the highway. The operators of both tractor and automobiles are factors to be considered in the accident.

NATIONAL COMMITTEE
ON
UNIFORM TRAFFIC LAWS AND ORDINANCES

525 SCHOOL STREET, S. W. • WASHINGTON, D. C. 20024 • TELEPHONE 628-2844

YULE FISHER, National Chairman
EDWARD F. KEARNEY, Executive Director

September 21, 1970

Mr. Douglas W. Toms, Director
National Highway Safety Bureau
Washington, D.C. 20591

Re: Farm tractors

Dear Mr. Toms:

The enclosed document responds to your recent request for a technical paper on the applicability of traffic laws to farm tractors.

Though the enclosed document briefly covers this subject, and includes any subject where the Uniform Vehicle Code mentions farm tractors, it has been designed primarily to provide references to other sources where more complete information on a particular point can be located by Bureau personnel.

Sincerely,

Edward F. Kearney

Edward F. Kearney
Executive Director

P.S. Because your study appears to be limited to "agricultural tractor accidents," our summary deals only with the farm tractor, that is, a self-propelled implement of husbandry which is designed and used for drawing other implements. We assume the Bureau is aware of the existence of self-propelled implements other than farm tractors which may present unique safety problems, and of the existence of towed implements which, when used in combination with a farm tractor, can have a substantial impact upon farm tractor or highway safety.

FARM TRACTORS, THE UNIFORM VEHICLE CODE AND STATE LAWS

Introduction

This document indicates those portions of the Uniform Vehicle Code (Rev. ed. 1968) that would or would not apply to farm tractors and briefly discusses the applicability of state traffic laws to the drivers of such vehicles. It was prepared by the staff of the National Committee on Uniform Traffic Laws and Ordinances in response to an August 20, 1970 request from the National Highway Safety Bureau for a paper on the subject of traffic laws as they apply to farm tractors. References to pertinent studies of state vehicle codes have been included, and, in some instances, the existence of any unpublished research is noted.

Registration and Titling

Unlike most motor vehicles, no certificate of title must be secured for a farm tractor or other implement of husbandry. Uniform Vehicle Code (UVC) § 3-102(6). See, however, UVC § 3-103, which allows the owner of such a vehicle to secure a title if he so desires.

As is true for all motor vehicles, registration of a farm tractor would not be required if it were never operated on a highway (UVC §§ 3-401, 3-402) or if it were merely being driven across a highway from one property to another (UVC § 3-402(2)). However, even though operated on a highway, registration of a farm tractor would not be required if such operation were incidental to its use as an implement of husbandry. UVC § 3-402(3).

State laws comparable to UVC § 3-402 on registration exemptions have been researched by a law student whose work is available at the offices of the National Committee, 525 School Street, S.W., Washington, D.C. 20024 (202-628-2844).

Driver Licensing

The driver of a farm tractor need not have a driver's license for operation that occurs at a non-highway location. This is true for drivers of all motor vehicles. UVC § 6-101(a).

For operation of a farm tractor on the highways, the Uniform Vehicle Code would require a driver's license but the laws of most states do not. See Traffic Laws Commentary

No. 70-1, Driver Licensing Exemptions, pages 18-21 (Feb. 6, 1970), for a complete review of state licensing exemptions for drivers of implements of husbandry.

Rules of the Road

Because no definitional or substantive exceptions have been provided, the driver of a farm tractor must comply with all rules of the road in UVC Chapter 11 that are applicable to the driver of a vehicle or a motor vehicle. Though most of these duties would involve highway operation, certain rules apply everywhere in the state -- reckless driving (UVC §§ 11-101 and 11-901), driving while under the influence of alcohol or drugs (UVC §§ 11-101, 11-902 and 11-902.1), homicide by vehicle (UVC §§ 11-101, 11-903) and eluding a police officer (UVC §§ 11-101, 11-904).

An examination of Uniform Vehicle Code: Rules of the Road with Statutory Annotations (UVCA) indicates that farm tractor drivers must generally comply with state rules of the road. The only possible exceptions are:

1. Three states (Kentucky, Oklahoma and Pennsylvania) appear to exempt farm tractors from rules of the road by excluding them from their definitions of "vehicle." UVCA § 1-184 (1967).

2. Five other states (Delaware, Missouri, New Hampshire, Ohio and Vermont) provide that farm tractors are not "motor vehicles." UVCA § 1-134 (Supp. 1969).

3. In North Carolina, farm tractors are excused from a prohibition against unreasonably slow speeds and drivers of such vehicles need not comply with any minimum speed limit. UVCA § 11-804 (1967).

4. Arizona excepts farm vehicles from its rule governing the movement of very slow-moving vehicles across railroad tracks. UVCA § 11-704 (1967).

Because farm tractors often are operated at speeds substantially below either the maximum limit or prevailing rate set by other types of vehicles, a few specific rules in the Uniform Vehicle Code might be noted. They are:

1. The tractor must be driven in the right lane or near the right edge of the roadway. UVC § 11-301(b).

2. Farm tractors may be excluded from controlled-access roadways or highways under a 1968 revision in UVC § 11-313. See the discussion of this Code change in Traffic Laws Commentary No. 68-1, Rules of the Road -- Revised, 1968, page 9 (Oct. 31, 1968).

3. A farm tractor should not impede the normal and reasonable movement of other traffic. UVC § 11-804(a).

4. The driver of a farm tractor must comply with any minimum speed limit that has been established. UVC § 11-804(b).

In addition to the rules in UVC Chapter 11, drivers and owners of farm tractors involved in accidents must comply with the reporting and other requirements specified in UVC Chapter 10. Under the Code, these duties are applicable to accidents that occur at highway or non-highway locations. See UVC § 10-101 and comparable state laws in UVCA § 10-101.

Equipment

Farm tractors are subject only to certain equipment requirements because of the exemption specified in UVC § 12-101(c). Under UVC § 12-215, a farm tractor must have two head lamps, one red tail lamp, two red reflectors, four-way flashers and the slow-moving vehicle emblem. A forthcoming issue in our Traffic Laws Commentary series will indicate the status of comparable state laws as of January 1, 1970.

Though farm tractors are not generally bound by equipment requirements, they must comply with equipment restrictions and limitations. For instance, provisions limiting the use of red lights visible to the front and sirens would ban any such equipment on farm tractors.

Because the periodic inspection requirement in UVC § 13-104 (a) applies only to registered vehicles and because farm tractors need not be registered, the Code obviously does not contemplate the inspection of very many of these vehicles. For a review of comparable state inspection laws, see Inspection Laws Annotated 56-61 (1969).

Width Limits

UVC § 14-101(b) exempts farm tractors temporarily moved upon a highway from limits imposed on the size of vehicles (such as the Code's width limit of eight feet). The texts of comparable state laws are quoted in State Restrictions on Sizes and Weights, 1 Motor Vehicle Law Series (published by the Highway Users Federation for Safety and Mobility -- formerly National Highway Users Conference).

Definitions

The Uniform Vehicle Code defines "farm tractor" and "implement of husbandry" in sections 1-118 and 1-125.

American Farm Bureau Federation

AFBF

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September 18, 1970

Mr. Douglas W. Toms, Director
U. S. Department of Transportation
National Highway Safety Bureau
Washington, D. C. 20591

Dear Mr. Toms:

This is in reference to your letter of August 20 in which you asked that we prepare a technical paper on the subject. In lieu of submitting a technical paper, we would prefer making the following comments and observations.

Farm Bureau members and the organization have had a long-time interest and program in farm and home safety. Farm Bureau policy on this subject, as determined by 1,865,854 member families from 2,814 counties in 49 states and Puerto Rico, provides as follows:

> "We recommend continued consideration and development of educational programs and activities to place more emphasis on safety in all areas.
>
> "We urge continued efforts toward the adoption of uniform vehicle codes and traffic guides.
>
> "We endorse such safety programs as slow moving vehicle emblems, defensive driving training, tractor roll bars (TOPP program) and the use of luminous clothing."

Considerable evidence is available to show that protective frames and crush resistant cabs, PTO Shields, and other safety devices have the potential to sharply reduce the number and severity of injuries to operators involved in tractor overturns and related accidents.

Persons operating farm tractors need to exercise reasonable care and to adhere to recommended safety practices even though the equipment is provided with safety hardware. Operator error cannot be totally controlled; thus, educational programs are needed as well as safety devices.

Safety devices can help only when used correctly. Overturn protection on tractors, for example, will give full protection only when a seat belt is fastened. PTO shields protect only when left on the equipment. Legislation and/or regulation cannot cause persons to have safe attitudes; this requires additional programs.

The farm equipment industry has been working for many years to improve the safety of machines to be used by farmers. Industry standards for product safety are continually reviewed and upgraded to improve the level of safety. Most tractors can now be purchased with overturn protection.

There is a need for more accident information in a standarized form. Through the efforts and leadership of the Farm Conference of the National Safety Council and others interested in farm safety, considerable progress is being made in working on this problem.

There are situations where overturn protection is impractical, such as on orchard and grove tractors where it would catch on trees or damage trees. Tractor mounted equipment also presents a special problem. Some mounted equipment provides some degree of overturn protection. Tractors used with loaders or blades inside barns or other buildings where door openings or ceiling heights limit the clearance present another obstacle.

High clearance cane tractors are used entirely in level land areas and are used with wide front axles and wide wheel treads. This equipment has limited use. Large four wheel tractors have a relatively low center of gravity and a unique weight distribution which makes them very stable and a backward overturn is highly unlikely.

There is also the difficult problem of providing safety equipment at a reasonable cost for old tractors. Many old tractors are still in use, but it would be unsatisfactory and very costly to provide overturn protection.

We appreciate the opportunity to express our views on this important subject. We know that, in the final analysis, that solution to safety problems is dependent, to a large degree, upon voluntary action and participation by the individuals involved.

Yours sincerely,

Charles B. Shuman

Charles B. Shuman, President

CBS:he

cc: Mr. Claude de St. Paer

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September 10, 1970

Mr. Douglas W. Toms, Director
National Highway Safety Bureau
U. S. Department of Transportation
Washington, D. C. 20591

Dear Mr. Toms:

Your letter of August 20 was referred to me in Mr. Baerwald's absence from the country. The Institute is honored by your request for its assistance in a study of tractor accidents. We deeply regret that we cannot respond positively.

Tractor-vehicle crashes on public roadways are relatively rare events. This does not mean that their reduction is unimportant -- it does mean that soundly-based conclusions as to causes and effective means of reduction require an arduous research effort. The time schedule imposed by the Congressional deadline for your report precludes such an effort.

We appreciate the compliment implied by your request and, again, regret that we are unable to assist you.

Sincerely yours,

Carlton C. Robinson

Carlton C. Robinson
Vice President

APPENDIX B

PROCEEDINGS OF THE PUBLIC MEETING ON AGRICULTURAL TRACTOR SAFETY

Agricultural Tractor Safety Meeting
Auditorium, Mark Building
Twelfth & Spruce Streets
St. Louis, Missouri
September 17, 1970

Conducted by
Department of Transportation
National Highway Safety Bureau
Washington, D. C.

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PROCEEDINGS

The Agricultural Tractor Safety Meeting was called to order at 9:30 a.m., September 17, 1970, in St. Louis, Missouri, by George W. Hartman, Director, Office of Systems Analysis, National Highway Safety Bureau, Department of Transportation, Washington, D. C., who presided.

Present: George W. Hartman, Chairman, and Joseph Delahanty of the National Highway Safety Bureau.

CHAIRMAN HARTMAN: Good morning.

This is a public meeting called by the National Highway Safety Bureau, Department of Transportation, to obtain information relating to the extent, causes, and means of prevention of agricultural tractor accidents on public roads and on farms.

I am George Hartman of the National Highway Safety Bureau. With me at the table this morning is Mr. Joseph Delahanty, also of NHSB.

Our purpose for being here is to conduct this meeting. You all should have a copy of the agenda of people and organizations who have asked that they be permitted to appear here today for the purpose of presenting their views or comments on this important subject. Copies of the agenda of speakers are available at the door if you did not pick one up as you entered the room.

We also would like to have you register so that we know who attended the meeting for the record.

As indicated in the published notice of this public meeting, Congress has requested the Secretary of Transportation to prepare and submit a report no later than January 1, 1971, on agricultural tractor safety set forth in section 8 of Public Law 91-265, signed May 22, 1970; and Congress has requested that the report specifically include, and I quote verbatim:

"(1) an estimate, based on the best statistical information available, of the number of deaths and injuries resulting annually from agricultural tractor accidents;

"(2) An identification of the primary causes of agricultural tractor accidents, including consideration of the hazards most likely to cause death or injury; and

"(3) Specific recommendations on means of preventing the occurrence of, and reducing the severity of injuries resulting from, agricultural tractor accidents, including such legislative proposals as the Secretary determines are needed."

In formulating recommendations to be submitted in the report, Congress has asked that careful consideration be given to the "advisability of establishing uniform Federal safety standards in the design and manufacture of all agricultural tractors sold in interstate commerce, requiring the installation on such tractors of safety devices, and providing assistance to the States in developing accurate reporting procedures for accidents involving such tractors."

Several approaches are being followed in preparing the report to Congress. Careful review is being made by a small NHSB task group of published reports, studies, and other materials available on various aspects of agricultural tractor accidents, causes, and safety measures. Assistance is gratefully being given by other agencies, such as the departments of Agriculture, Labor, and Health, Education, and Welfare, by a number of colleges and universities and by the National Safety Council and other organizations.

Field visits have been made by members of the task group to tractor manufacturing plants and to tractor test and farm operating facilities.

A number of recognized, outstanding researchers or experts have been invited to prepare and submit technical papers on a number of selected tractor safety topics. The response to the invitation has been excellent and the papers will be included in the report to Congress.

In order that all persons and organizations having views and comments with respect to farm tractor accidents, injuries and deaths may be heard and reported on, this public meeting has been scheduled. A notice of the meeting was published in the Federal Register dated August 21, 1970, and was given the widest distribution possible through a press release, through letters to about three hundred farm papers, publications, and to farm organizations, commodity groups, land grant colleges, and to the tractor industry, and through the use of a broad distribution list provided by the United States Department of Agriculture.

The purpose of this meeting, then, is to obtain views and comments from those who might not otherwise have the opportunity to be heard and who have signified their desire to appear here today. As the agenda indicates, a full day's schedule is ahead of us, so we must hurry.

The agenda for today accommodates all people and organizations that have requested time to present views. If there are others here today who wish to be heard, and if there are a sufficient number to make it worthwhile, we will schedule a continuation of the public meeting tomorrow morning. If there are people who wish to appear but not in sufficient number to warrant holding over the meeting until tomorrow, we invite submission of comments in writing so that they may be placed in the record. Those who wish to be heard but who failed to make the fact known in time should fill out a request card at the back of the room before 12 o'clock noon today.

Bill King is standing in the aisle back there, and he has forms that you may fill out if you so choose.

If time permits at the close of the meeting today, the auditorium will remain open for a while for a question and answer discussion. This discussion, however, is not part of the formal meeting in that no transcript will be made and appearance will be entirely voluntary on the part of those who present views today.

Because of the tightness of the schedule, we must ask those on the agenda to speak briefly and within the maximum time limit indicated. You will note that the schedule does not provide for a "break". If speakers will take a little less time, we can have a mid-morning and mid-afternoon break, as well as have time at the end for a voluntary give and take discussion.

Speakers may find that others before them have presented views which are identical to or substantially the same as theirs. In this case, if the speaker would simply indicate it or delete or foreshorten the points to be made, repetition may be avoided. If a written text of omitted points is provided us, the views or comments will be placed in the record in their entirety by the court reporter.

Thank you.

The first organization to be heard this morning is Top Operator. Would Mr. Norman Cavender, Managing Editor, please come forward to present his views.

We note that you are afforded the maximum time of fifteen minutes.

MR. CAVENDER: My name is Norman Cavender. I am Managing Editor of Top Operator, a Farm Journal publication, 230 West Washington Square, Philadelphia, Pennsylvania 19105.

I have a very strong interest in agricultural safety, having survived a tractor accident that could have been fatal and having been present when another man did not survive a tractor accident. Moreover, it is my job as an editor to provide farmers with information relevant to their well being, so I speak today from both personal and professional experience.

In preparation for this meeting I requested the Farm Journal Research Service to conduct a national survey of farmers, asking them a series of questions pertinent to these efforts. I will present this information as well as other information I have developed.

In late 1967 through all of 1968 I spent virtually full time researching farm accidents for a series of articles. I finished this project with the strong conviction that our information on farm accidents is sadly deficient. In my opinion, our most urgent need is to correct this as soon as possible so we can take the steps necessary to reduce tractor fatalities.

There are a few fortunate exceptions to this problem of information. States like Iowa, Kansas, Michigan, and Ohio, to name just four, are providing very valuable information on accidents. Information of this type has significantly reduced tractor accidents where it was put to use.

But tractor accidents are a national problem, and despite progress in some states, we do not have the quality or quantity of information we need to deal with them on a national basis. In many areas of the country the available reports on tractor accidents are little more than newspaper clippings lacking the most vital information. Yet these get recorded, projected, and expanded until we have to try at the state or national level to base safety efforts on material from the popular press, often third- or fourth-hand information at that. Although I doubt it is necessary to tell this audience, I can assure you, as an editor, that there is considerable difference between scientific research and general news gathering.

In my efforts to get valid information on tractor accidents I learned we have many times more information on protecting crops from insects than on protecting farmers from machinery accidents. Usually the research material I found listed "cause of accident" as "tractor overturned" or "caught in pto shaft." This is about as meaningful as a doctor listing on a death certificate as cause of death "heart stopped beating."

On one occasion I checked out four tractor accident reports with on-site inspection and interviews with the persons involved. The accident descriptions on the reports said nothing more than "tractor overturned." I found that all four tractors involved were over 15 years old, and 3 were over 20 years old. Two of the four accidents involved mechanical failures due, as far as I could determine, to the age and wear on the equipment.

On another occasion I checked out 13 accidents involving equipment attached to a tractor. In 9 of the 13 accidents the equipment was over 10 years old, and in 5 of the 13 it was over 20 years old.

Although this was a very limited sample, it indicates a significant field for tractor safety activity. Currently there are almost five million tractors on United States farms. During the past ten years the industry has sold approximately 1.6 million farm tractors, or a replacement rate of about 33 per cent of the tractor population every ten years.

Based on these figures, 66 per cent of our tractors could be between 10 and 20 years old, and 33 per cent could be between 20 and 30 years old.

Age of equipment should have a vital bearing on our safety efforts for two reasons: First, there have been substantial design changes in tractors that make current models more stable and generally safer than the older models. One of our reporters recently notified me that he attended a safety demonstration during which engineers planned to overturn a late-model tractor to show farmers how and why such accidents happened. The engineers had constructed an incline and had sent the tractor on its way, operating it by remote control. But it did not overturn as planned. It required repeated efforts to topple it.

Perhaps we will see a reduction in tractor overturns as these more recent models replace older ones. But without valid data on tractor accidents by age and model, we can't be sure and we may not know how to take full advantage of such design changes.

The second reason why tractor age is important is the farmer's habit of putting his older tractors into standby or utility use. Often, the utility operations are the most hazardous: cleaning ditches, mowing on inclines, operating earth-handling implements on rough terrain. That would indicate that the use of the older tractors is a definite hazard. But many times older tractors are used in a stationary mode, to operate grinders or blowers. Or they may be used so infrequently to pose no appreciable hazard. Again, without valid data, we do not know, and we cannot take effective steps toward safety.

Nor do we have valid data on a national basis relating tractor accidents to terrain, weather, types of operations, equipment attached, skills of the driver, and so forth. We do not even know if alcoholic beverages are a factor, although from what I have seen I suspect this could be the case at least infrequently.

For that matter, I am not sure I know even what our work-accident fatality rate is in agriculture. A commonly used figure for 1969 shows 66 deaths per 100,000 workers. This is based on Department of Labor worker reports. But as an agricultural editor I usually depend on Department of Agriculture reports as valid indicators. The USDA worker count reflects a death rate of only 53 per 100,000, or a reduction in the stated fatality rate of a full 20 per cent.

We have seen marked progress in tractor safety, in fact, in farm safety in general, in states that have developed and implemented safety programs based on careful research into the causes of accidents. The Slow Moving Vehicle emblem program is an excellent example. Yet we have only a handful of states with systematic, professionally managed safety programs. In my opinion even these states have inadequate funds for the job that could be done. Progress has been made through the exceptional efforts of safety specialists, aided by volunteers. With additional support for these programs, we would see further reductions in tractor accidents.

So I urge immediate action to develop and implement a comprehensive, national program to investigate tractor accidents and develop information that will reduce these accidents. I recommend that every tractor fatality occurring in the United States be professionally investigated, if not on a continuing basis, at least as a first measure toward reducing tractor fatalities.

I have repeatedly stressed the need for accident information on a national basis, rather than a state sample basis. I consider this vital to an effective safety program. Samples are not sufficient in agriculture. Problems of automobile accidents are relatively uniform across the country. There are, of course, variations in state codes, highway design and maintenance, weather, traffic congestion, and so forth. But these variations are minor compared to the situation in agriculture.

In the past ten years I have logged almost 500,000 air miles and countless highway miles traveling throughout the country. I have made frequent and lengthy visits to farms in almost every area of every state in the nation. I know many roads in states from California to North Carolina, Minnesota to Mississippi, almost as well as the streets in my own neighborhood. Despite this familiarity, I never travel without being amazed at the incredible diversity of farming practices and conditions in this country.

In many cases it is almost impossible to apply information from one area of the country to the problems of another area. A study of accidents in Pennsylvania involving a tractor, a mold-board plow on a three-point hitch, and rolling land may have little meaning to the farmer operating a massive, four-wheel-drive tractor with pull-type disc plow in the Texas High Plains.

Pto accidents in Minnesota forage crops do not apply to the Mississippi cotton grower who uses a tractor only as a tillage tool. I know many farmers who have never even uncapped the pto outlet. It would be possible to change the pto design for the benefit of some farmers and in the process do nothing but add unnecessary expense for other farmers.

We even run into problems with protective frames. There is almost universal agreement on their value. But let me point to the other side.

I seldom go into the vegetable-producing areas of Florida without hearing that another tractor has been dunked into a deep drainage canal. In most cases the driver simply swam out. Protective frames and safety belts could be a handicap to this man, or to his counterparts in the irrigated fields on the West Coast.

Crop requirements even enter the picture. Operators of citrus groves, orchards, and nut groves go to considerable lengths to protect their trees against equipment damage. Broken limbs and damaged trunks permit the entry of diseases and insects. So the farmers frequently wrap their tractors in sleek metal shrouds so nothing protrudes to catch the overhanging limbs. The protective frame that is nothing but beneficial in the corn field can become intolerable in the groves. I know many citrus growers who suffer heavy dust and high temperatures in southern summers because clearance problems prevent the use of an air-conditioned cab.

Even the matter of 10- or 20-year-old equipment varies from region to region and crop to crop. Some of our crops are in better shape economically than others. Here you find equipment replaced more rapidly. In other crops and other areas farmers are forced by economics to squeeze as much life out of their equipment as possible. So action at the Federal level will have to take into account these varying situations. And I have given only a few of many such examples.

I speak from experience when I say this diversity is no small problem. As an editor of a national magazine, I spend the greatest portion of my time wrestling with the immense problem of relating information developed in one area of the country to the needs and practices of another. This diversity is so wide and so deep that our parent magazine, Farm Journal, has been forced to computerize the contents of each monthly issue just to manage the page changes from one region of the country to another. A recent single monthly issue of Farm Journal was published in 213 different versions, each version containing page changes necessary to provide appropriate information for different regions and commodities.

This, too, is why I stress the necessity for a comprehensive, nationwide program to analyze the problems of tractor safety and why I would caution against any broad actions based on studies from specific areas without a complete understanding of the effects such actions would have elsewhere.

Thus I urge that any program to reduce tractor accidents be formulated with as much freedom and latitude for the farmer as possible. In agriculture, safety does not deal with one industry; it extends to hundreds of industries, from the production of tung nuts in Mississippi to strawberries in Oregon. Many farmers may use the same tractor in vastly different ways. An effective, reasonable program must take this into account.

One other point enters here. Farmers show a strong degree of self-reliance and individualism. A person may or may not agree with that attitude, but I think it must be respected. These farmers have given us the world's finest supply of food. The United States housewife spends a smaller portion of her family income on food than does the housewife in any major country in the world. Large credit for this must go to the farmer's sense of individualism.

This freedom to be his own man is one of the main reasons he continues to farm. Certainly the economics of farming are not overwhelmingly attractive. According to USDA figures, farmers in 1969 realized a net income of $16 billion on assets of $298 billion. This is a return to the farmer of only 5-1/4 per cent total for his assets, his labor, and his management. And that figure includes Federal payments and such non-cash income as the farm products his family consumes.

Thus the average farmer could sell out, put the proceeds into a savings institution and, without leaving his rocking chair, get as much annual income from the interest as he now gets working his farm 60 or more hours a week.

In the 10 years from 1958 to 1968, his taxes per acre went up amost 200 per cent. His interest costs per acre went up 400 per cent. One of the few bright spots was his farm machinery, which rose in cost only 36 per cent.

So I urge you to keep this economic situation in mind. The farmer cannot afford costs in money or time that are not justified by the best possible information.

And I urge that you give full consideration to the farmer's personal desire for independent and individual choice. I feel a safety effort would be far more productive working with these attitudes the farmer holds rather than against them.

You will see a strong reflection of this in the accompanying survey. It was made on a random national basis. The results I am submitting here run to twenty pages. We have included quotes from each of the one hundred farmers indicating why he answered yes or no to specific questions. I will simply give you the highlights here.

Question 1, in the last five years has anyone on your farm had a tractor accident resulting in injury that required medical attention? Six of the one hundred answered yes. Two fell off the tractor, one drove in front of a train, one slipped off the step getting on the tractor, one was burned taking a radiator cap off, and one could not recall specific details.

Do you think tractors need more safety features than they have now? 46 per cent yes, 54 no. Of the ones saying yes, the roll bar was the most widely recommended safety feature.

No. 3, do you think the government should require tractor operators to qualify for tractor drivers license? 89 per cent said no.

No. 4, would you like the government to inspect your tractors periodically, perhaps once a year, to make sure they are in safe operating condition? 86 per cent said no.

Would it be helpful if you had more information on tractor accidents and ways to prevent them? 63 per cent said yes.

Then we asked them for their ideas and the best way to reduce tractor accidents in the United States. These are heavily weighted toward training and driver responsibility. They are all reflected here.

You will see two encouraging responses in this survey. One is the acceptance of the roll bar on a voluntary basis by these farmers. The recent campaigns to get this message across have gotten through to the farmers.

The most overwhelmingly positive response to any question was to Question No. 5, would more information on tractor accidents be helpful? The farmers requested information on the causes of accidents. Of those who answered this question in the negative, a significant number did so because they felt they were already getting good safety information. A quick check showed this type of response usually came from one of the states with a solid program already in operation.

One farmer suggested periodic information detailing the causes and consequences of recent tractor accidents. This is a sound idea, and I can assure you Farm Press will offer its cooperation in such an effort.

I have voiced several cautions today. I did not do so to discourage your efforts at safety. On the contrary, I want to see your maximum success in this vital problem. But I am aware that the problem is also complex, and the tractor is just one element in the machinery-accident picture. It would be tempting for me to say that we know already that additional guards and protective frames can save lives, so let's get them on without another week's delay. But this would be a narrow view. The farmer has other machinery than tractors. If we can work with him to eliminate some of the causes of accidents and to get his full, deliberate cooperation in the tractor-accident problem, we will have made large strides toward solving problems with other machinery and other activities. So although this is not your specific concern, I ask you to keep it in mind.

I am confident that an adequate program of information development and distribution, coupled with continuing engineering improvements, better training, and better protective devices, will substantially reduce the problem of tractor accidents. And I am confident you will find the farmer receptive to measures that help him produce our food safely and more efficiently. I can assure you, from my experience with him, the American farmer is very much concerned about safety in agriculture. And he is a professional, with professional skills in machinery. Given the assistance he needs, he will reduce the accident rate.

Thank you.

CHAIRMAN HARTMAN: Thank you, Mr. Cavender.

Do you have a copy of your remarks in writing? We would appreciate your leaving them with the court reporter.

(The survey results referred to follow:)

1. In the last five years, has anyone on your farm had a tractor accident resulting in an injury that required medical attention?

YES

Two years ago, boy (16) fell off. He was dragged underneath the manure sprayer. In hospital 40 days---crushed ribs. He was the operator.

Fell off tractor. In hospital 9 days---blood clot in leg.

Drove in front of train and hospitalized overnight, but no serious injury.

I can't recall the exact accidents in the past years because there long ago. But there have been some.

I slipped off the foot stool on the way up to the cab of my tractor and cracked a couple of ribs.

About 5 years ago a man took the radiator cap off and forgot to idle the tractor before he took it off and he got burns all over his arms and hands.

2. Do you think tractors need more safety features than they now have?

YES

Roll guards, they should be standard instead of optional.

Roller bars should put on tractors in case of a turnover.

Roll bar

Could not think of any safety features

Put roll bar in cab to help driver in case the tractor ever turns over.

Just careful driver and good equipment to use.

Anything that makes operating a tractor easier.

Roller bars should be used in case the tractor tips over. Should have more schools for younger drivers.

Anything that can help to reduce accidents.

Work on putting roll bars on all the cabs. Everyone should have a red light signal which are now out. For nighttime especially.

Roll bars---protects people when tractor tips over.

Roll cages. Keep tractor from rolling over---less noise.

Slow them down.

Roll bars. Red reflectors and lights on back.

Roll bar

Roll bar

Less speed

Roll bar

Roll bar

Normal improvements---long ways more in comfort to reduce driver fatigue

Front end needs to be heavier.

Trapping to protect from rolling over-roll

Comfortable riding, rounder seats. Shield or frame---roll bar.

Roll bars would be best.

Tipping over backwards---too light in front.

Has to do with operating tractor---not on tractor itself.

If operating on hilly ground, you need more safety features---he operates bottom ground.

Better shield for moving parts.

Roll bars & seat belts.

More roll bars. Other than that, couldn't think of anything.

Roll bar---different steering mechanism.

Roll bars---more lighting for night driving.

More roll bars for hilly ground

More roll guard

More roll bars

More roll bars

More roll bars

Better operators

Don't know in particular, but things can't be too safe.

Better guards to shield the driver.

Roll bars are wonderful. Would like heavier front ends for pulling attachments. Do not like tricycle front (narrow wheels). Should have wider front ends.

No idea---he has men to operate tractors, not himself.

Roll bar---cab.

Don't know of change or features

Don't know right off hand.

Roll bar

3. Do you think the government should require tractor operators to qualify for a special tractor drivers license?

YES

Could depend more on drivers if they were licensed.

Most older experienced driver drive okay, but the government should make people qualify. It seems as if it would be a hard thing to do right.

If the person who is operating the tractor has not been around tractors all his life, he would need to have training.

Would help accident rate.

Only if they live on a main highway.

Have to know controls---some are complicated and need drivers who know what they are doing.

Some drivers are reckless and would eliminate many accidents if drivers were qualified.

Depends on where you drive---in city or on farm. Some operators are not good drivers.

We'd have more careful and capable operators.

On heavy tractor equipment rather than wheel tractors, I think a license should be required.

It would be beneficial to the farmers because then they know they're getting a qualified and experienced driver.

NO

A lot of farmers have their children 12-17 drive their tractors. If they needed a license they could not get one because of age. Result: more cost to farmers for drivers.

Why should they be required?

We have good drivers but if they set up a test for tractors drivers some good drivers would not pass. But yet they are good drivers on the farm and are careful.

It's not government property---they have nothing to do with it.

His boy drives the tractor.

Not necessary---they are mostly off the road and not in traffic.

Most tractor operators are, on the whole, pretty careful.

Experience is the best teacher. Young person should be supervised but other than that it is not necessary to have a license.

Drivers can get all the experience they need on the farm.

Most farmers are capable of operating tractors safely, having been brought up on a farm.

Matter of experience---can't be taught.

Experience is best teacher.

Most anyone could learn to drive a tractor with a little practice.

Too much government influence---tractors do not cause most farm accidents in that area. Mostly combine and picker accidents.

Farmers have enough trouble getting labor without having to worry about getting one with an operator's license.

Too much government influence now.

Not too many are used on highways, so they aren't a safety hazard there.

Isn't a number on highways. Young children taught early to operate safely.

Everything has been okay so far.

Young boys trained early and well on farm.

Age limit not important and license would require age limit.

Most farmers are capable drivers and should not have to have a license.

Most are growing up on the farm and are taught safety on a tractor. It is instilled in them at a very early stage.

Lots of farmers are experienced drivers. Personal attitude toward your tractor give you more respect for your tractor.

No real need; most people are aware of how to operate tractors but don't do it all the time.

Government should be kept out of people's business as much as possible---already has too much say.

No license---but should have a school for all tractor drivers.

Government should not be involved in our business.

Too much government control. Farm organizations could take care of that to teach operation without government.

Too much government control now. Farmers know when tractors are safe or not.

If you can drive a car you can drive a tractor---no special training is required.

Government is involved in too many things now. Most operators are qualified enough.

Don't see the purpose. Most drivers have grown up on farm and have driven since 8 or 9 years old. Most are good drivers.

Don't think it is necessary. Most drivers are qualified.

Wouldn't be able to get drivers if you had to hire special drivers.

Men grown up with it on farming but if you have to hire outside help, they should be trained.

Too complicated. Training for under 16-year-olds would be helpful, but operators are for the most part careful.

Farmers are specialized in farm operations on tractors. They use equipment everyday and know how to use it.

Don't think it is necessary. Farmers can operate well enough.

Very short stretch to drive and not necessary to have special license.

Farmers know how to drive and for the most part are careful and operate well.

All drivers are capable because they are trained young and know what they are doing.

Government is in too much now.

Would cost too much and raise prices.

Just gets too involved. Would rule out younger children and they are sometimes better drivers than the older farmers.

Most are born and raised on farm and can operate tractors safely.

Government interference---more red tape.

Government has enough controls already.

Old enough to operate.

Competent operators use the tractors.

Leave well enough alone.

If you're young, and to have a tractors drivers license, you might not be able to get a job.

Most tractor drivers are capable drivers in our area.

Too much government control now.

We have enough expenses now.

Have capable operators now.

Not necessary. Most of them are not on the highways---they are used mostly on farms.

Running on farm not required. Using them on highways a lot may require one.

To operate on your own farm no license is necessary, but some do careless driving on highways. Maybe a license then would be necessary.

Capable operators are driving tractors.

Not necessary.

You use it on your own farm---you're not interfering with anyone else.

They have their hands in too many things now.

Good idea.

Some of our farm help wouldn't be able to pass a test. Not because they can't drive, but because some haven't too much education to read.

That wouldn't help. Only needs common sense---anyone can drive tractor.

They already know how to drive before they are allowed in the fields.

Around here there isn't any accidents that I know of---doesn't require a license.

Children are raised up on a farm and know how to drive a tractor at an early age.

Government is in too much of our business now.

I started driving at 9 years of age. Most boys raised on farms start at early age and are taught right from the beginning. They don't need a license.

It is too simple to operate now. Don't need a license.

Not unless they go on public highway.

They are simple to drive. Maybe old people, not young or middle age.

We can get by as it is. Simple to operate.

The operators are careful if well trained at the beginning.

The government has too much to do now.

You need experience to have a good tractor driver so you have to start them young. We have mostly farm boys.

My sons have been operating them since they were 9-10 years old and they're just as good as anyone with a drivers license or a 16-year-old. They know more about it, too.

It's not whether you're qualified, it's the experience you have.

You have training through extension service and school learning. I think that should be enough.

Because there are still some people who have drivers licenses and still don't know how to drive.

The goverment has too much to do already.

Most tractor drivers are qualified and they should just watch so not to be careless.

If the person has some kind of a certificate it's good, but there's no need to take a test just to run a tractor.

Would not make them any better drivers.

All farmer's kids know about operating tractors---does not think it is necessary.

Unless the tractors are going to be on the road all the time---no need for a license.

It would put too much of a hardship on us if they did because our kids help us out.

4. Would you like the government to inspect your tractors periodically---perhaps once a year---to make sure they're in safe operating condition?

YES

Catch faulty ones, both operator's fault and manufacturers.

Has worked well with cars. Some owners let equipment deteriorate and then neglect to tell operators what is faulty.

He doesn't need it but some farmers need to take better care of their tractors.

We trade every 2 years but other farmers cannot afford it. Some let the tractors go, as far as care is concerned.

Some farmers are careless about tractors and the way they handle them.

Might make farmers keep equipment in safe working condition and have less accidents.

Some of the tractors are not safe on roads.

Safety precautions.

Some are not safe to be driven on highways.

Keep from having accidents

Safety precautions

Some farmers don't keep their equipment, so if they knew they were going to be inspected they'd keep the equipment in good shape.

On farms no one is qualified to know everything about a tractor. If it didn't cost the farmer money.

NO

The government already has enough to do.

We keep them in good condition.

Doesn't make any difference what the government does to the machine cause if the machine doesn't operate in the fields it's not going to operate at all.

Would not help. I don't know why---it just won't help.

The farmers keep the tractors in good condition.

It's not like a car. Sometimes it's the driver that needs inspecting and not the machine.

We're already hampered by the government too much. Why should they tamper with our private property?

Tractors move rather slowly, so what's the sense?

Farmers keep their own tractors since they have to depend on them.

I feel the government has their hands in too much of our business already.

Each farmer should know his machine and should know whether or not it is in safe operating condition.

It's sort of needless. Maybe it wouldn't hurt, but why do it.

The government have plenty to do already.

Farmers know how to take care of safety conditions.

It's up to the farmer.

It's just a lot of red-tape. We keep our tractors in shape. If they weren't we couldn't use them.

The farmer or operator of the tractor knows if the equipment is in safe operating condition.

The government shouldn't have anything to do. Government controls enough.

We already have our tractors registered and inspected. (Massachusetts)

Nothing they could do. We know how to inspect our own tractors. Manufacturers know what to put on tractor for safety.

Private enterprise. Maybe local inspection---not government.

Would rather not have the government have anything to do with it.

It's your own tractor and you use it on the farm, not on public roads.

Each operator should know if his tractor is in good operating condition.

The farmer usually keeps it in shape.

They would always be finding something wrong.

I can do that better than a government man.

Same as car inspection. Cost money and put sticker on. Always finding something.

They aren't driven fast enough to require an inspection.

We know how to take care of all of our farming equipment.

My own business what kind of tractor I run on my farm.

Keep mine in shape anyway. I wouldn't need anyone to tell me.

Because they are used mostly on farms and the farmers keep them up.

Unnecessary.

I don't need government to tell me when my tractors in operating condition.

Farmers take very good care of their tractors.

If it runs it'll be safe enough.

Have it done regularly and don't need government involved.

Too much government red-tape.

Just that much more expense for farmer.

Too much government interference already.

Couldn't afford government interference.

Government is involved in too many things now.

Not necessary to involve government.

Farmer is capable of doing it himself. No need for government interference.

Government has enough expense without running around doing that.

Operation and repair of equipment is farmers' business.

Take care of own---too much red-tape.

Don't think government should be involved.

If I can't keep it in good condition myself, the government can't send someone to do it. It would mean more expense.

Farmer knows own equipment and keeps it in good condition so he can farm better.

Have enough government inspection.

Tractors go to local mechanic to repair. They get good going over and are kept in good condition. Government men couldn't do any better.

Government has nose in our business enough. Don't need them in this, too.

Good operator knows more than government inspector from what I have seen.

Don't want government involved in anyway at all.

Not necessary. Tractors are kept in good repair.

Tractors kept in good running condition. Should not be inspected. No need for it.

They have no business inspecting my tractor. That's my business.

Doesn't want the government to have anything to do with it.

Too much government control. Individual control should be emphasized.

Responsibility of owner and operator, not government.

Farmers have a qualified man to take care of tractors. They know the tractor will work. Tractors are very important.

Most farmers keep their tractors in good shape.

We rely on the tractor for our living so we keep them in good condition. Pride in tractors.

Not too much can go wrong with tractor. The driver is at fault, not the machinery.

Farmer's responsibility.

Expense and trouble to both parties that is not necessary.

Up to operator.

Expense---many people can't afford to buy new tractors should their old tractors fail inspection.

Too much expense.

Operators should check themselves.

The farmers have to have them in good shape.

Farmer's responsibility.

Doesn't know what an inspection would prove. To stay efficient, tractor operator should keep up his tractor.

Farmer uses good judgment about their tractor and take care of them.

Would not be too much to inspect.

Take care of that ourselves.

Do not run fast enough for government to inspect them.

Doesn't make any difference to him.

Just another government expense.

Isn't necessary. Operators are usually careful to make sure their tractors are in good working order.

Most farmers keep their equipment in good working order themselves.

Most farmers can keep the equipment in good condition.

Operator knows more about the operation and maintenance of a tractor than the government.

If he is a good farmer he already has it done.

5. Would it be helpful if you had more information on tractor accidents and ways to prevent them?

YES

Don't know.

Don't know.

Proper operation---agricultural Extension service.

Stress to use safety devices already on tractors.

Causes of accidents.

Possibly classes on tractor operation. With youngsters, 4-H clubs helpful.

Ditch--how to keep from tipping. Causes of accidents.

No comment.

Causes.

Steep slopes problems. Causes.

Causes of accidents.

Causes of accidents.

Why---the cause of accidents.

Vocational education program.

Tractors upsetting. Ways of preventing.

Don't know off hand.

Locking brakes together. Slowing down for a turn. Slowing down on rough roads.

Speed---less speeding.

General information.

Research from university. They put out good literature.

Don't know---hadn't thought much about it. Information is always helpful.

Information to relate to possibility of accidents put on tractors to watch what needs to be done.

Tractor training for younger boys on tractor safety.

Tractor safety. Publicize the best way to prevent accidents.

Any information on operating and caring for tractors would be helpful.

How accidents happen. Sometimes it might be something you would never think of.

Which would be the way.

Anything that would make drivers more careful.

Causes of accidents and cautions for all drivers.

More information on prevention. Should tell capabilities of tractors.

All types should be available.

What would be helpful.

Could not think of any information.

Causes of accidents.

Doesn't know.

Safety program might help young drivers.

Safe driving practices information---especially for young drivers.

Doesn't know any particulars.

Some farmers aren't aware of some of the things that you shouldn't do on tractors.

Information for tractors driven on road. Drive too fast. Free wheeling tractors are dangerous on the road.

Any kind of information would be good to have.

We have good drivers. Some could use information on care or running tractors. More information would not hurt anyone.

Information on operating.

For young people---about taking short turns, too much speed on hills. Making proper brake adjustments.

Main causes of accidents. Prevention. Stress that tractors are dangerous for non-qualified people.

For the public mostly---find out why and how accidents happen.

Stress danger points to farmers. Educate beginning drivers to what a tractor can do and what it can't do.

Something to keep the tractor drivers aware that accidents can happen because of carelessness.

I think, like in hilly regions, farmers should be posted what to do in cases of their tractor raring up on certain grades. This should be pointed out and roll bars should be explained. They should work with the government.

Doesn't know.

Causes for accident.

Turning at high speeds and how to check your tractor.

What the most hazardest things are.

How to start the tractor. Why you shouldn't take chances in filling silos and packing them down. Also to be careful of ditches on the sides of roads.

Government should put out a bulletin to post the farmers on the different kind of accidents that have happened so they can watch out for them.

They should compile all the reports on serious tractor accidents and tell how and why they happen.

Information on maintenance and in case of fires.

I'm always ready for any information on any type of farming and its equipment, but what kind right now I don't know.

No comment.

Handling in all kinds of soil, if hills or on level ground.

What causes accidents. What would reduce accidents.

Overloading, fires, driving on roads.

Amount of hillside driving without tipping. Where to hitch chain to prevent tipping.

NO

Most accidents are carelessness. If operators used more common sense, there would be less accidents.

Never had any accidents. Land is so flat---not that many accidents around.

Use good judgment---that's all it takes.

Use common sense. Accidents are caused by carelessness.

Experience is the best teacher. Just be careful.

Will not make me operate a tractor any more safely than I do now.

If accidents happen, they'll happen.

There is enough information already available.

Wouldn't help any.

Not as serious as it is made out to be.

Accidents are caused by carelessness on drivers part. More information would not help carelessness.

You just have to be more careful.

We read in magazines about accidents. Most are carelessness on the part of the operator.

Common sense and good judgment should be enough. People don't read information anyway.

Read and are cautious enough.

Lots of information available now if you want to be informed. Tractor companies put out plenty of information.

If you are careful you can prevent accident. You don't need information to be a good driver.

If you are careful and you know what you are doing you can operate safely.

Most people have good judgment. Operators know when they're in danger. Most drivers know what the dangers are.

I just don't think it would.

County agents and farm magazines have made it available if people want to look for it.

Most accidents are caused from carelessness, not because they didn't know how to operate.

Logic is the factor that causes accidents and people don't think logically or they wouldn't have accidents.

Wouldn't help any---carelessness causes most accidents.

University makes this information available as do farm safety directors in state. Adequate information.

Caution prevents accident and you can't teach carefullness.

We know what causes accidents and we are careful.

Now too many accidents---it isn't necessary.

Most drivers know what to do.

Most farmers know what to do to drive safely.

Not where I'm concerned.

I really don't know.

I feel I know all I need to know.

Most tractor accidents are just carelessness.

Never heard of an accident since the old Ford used to back over the tractor. Brakes weren't too good sometimes on those old Fords.

All these years of operating a tractor, farmers usually knows the ways of preventing accidents.

Anyone that runs a tractor knows the dangers the same as dangers in driving a car.

6. What do you think would be the best way to reduce tractor accidents in the United States?

Be careful, some type of schooling or test for heavy tractor equipment.

That is up to the driver not getting excited and not being careless.

Never heard of accidents that were really bad. The best would be a longer draw bar.

Fatigue is a big part of the problem and so is carelessness. If they paid us more we wouldn't have to work as hard.

By not being in such a rush. Reduce the time and learn carefully.

Not doing any farming.

To have responsible drivers to stop carelessness.

Safer driving.

Stress using common sense.

Doesn't know---there haven't been many accidents in the area.

Keep the kids off the tractors.

Get qualified operators.

Safety campaign, but would be a difficult job.

More care should be taken by operators.

Stay off tractors.

Education of drivers.

Carelessness---not paying close enough attention to what you are doing.

Require roll bars and safety programs.

Drive carefully.

Emblem on tractors helps. Drive Safely---No Sharp Turns etc.

Being careful would reduce accidents.

They don't need a way. Doesn't think there are that many accidents to be concerned about.

Operator could reduce accidents most. Less carelessness on operator's part.

Don't know.

Don't know how to answer.

Highway speeds. In field operations, by doing work with experienced operators on tractor and operators are careful.

Don't know any way.

Don't know---most accidents are caused from overwork and careless driving.

Use good judgment and less speed.

Publicity to call attention to causes.

No idea.

Keep the public aware of the speed of the tractor on highways.

Be more careful---like driving a car. We don't drive fast.

Shouldn't let small children drive tractor. Usually if there are accidents, it is children.

Just be a little careful in driving is the best way.

Don't have any idea.

Slow them all down---not a speed vehicle.

More instructions in instruction book on how to operate tractor.

Train minors. Could try driving education for tractors in schools like driving cars.

In our area, accidents are not a problem. Can't think of any accidents in 40 years I've been farming.

More knowledge for people around tractor.

Education of the driver.

More capable operators. Keep young children off of tractors.

Use wide front-end tractors. Use more protection around the PTO shaft. PTO shaft is where you hook up hydro equipment.

To compile all the information possible on why these accidents happen and give us the information.

There are so many tractors driving on highways now they should have signals of some kind. Also information on driving on hills with tractors.

Use experienced help. Make sure they know what they are doing. You have to find them and be sure. Our farm boys are the most experienced because they start young and they know what they're doing. These city boys that want the jobs need more experience and a lot of practice. Our schools are giving good education to the kids on the matter of operating tractors.

Tractor makers could do more in research to help make a tractor safer to drive.

Being a careful driver is the best advice.

For all drivers to be more careful.

Everyone to be more careful.

I think it's a matter of training the people. I start out with young high school boys and teach them all I know. I tell them fully all the points they should know.

By education---just to keep them mindful of the fact that carelessness can result in an accident.

More education for drivers as to how to operate a tractor and keep it in good repair.

Education on operating and maintenance of tractors.

Fells most tractors accidents are caused by people playing around them, not by not careful operation.

Making people more aware of the dangers. Tractors will pick up in front end and roll over.

Cut down speed on tractor.

Don't know.

Get a safer way to travel off the highway.

Have the tractors with power steering and brakes to have a little more free-wheeling when the motor cuts off while working so he could handle the tractor easier and keep it under control.

Make sure operator is cautious and qualified.

More caution on driver's part.

Careful driving.

Make sure drivers are qualified.

Training course for young people.

Make them safe to use on streets. Better brakes.

Row bars---seat belts. All of these sum to help keep down tractor accidents.

Most accidents happen on unlevel land. Find out why the tractors tip over so easily.

Stop underage drivers from operating tractors.

Make drivers realize that tractors are for use in fields, not for riding people around. Feels most accidents are caused by having people on tractors who don't have seats on tractor.

Additional information on causes of accidents and ways to prevent them. Make everyone more aware---more careful.

For everyone to be more aware of danger.

Give tractor operators schooling on driving and care of tractor.

Make sure they know how to operate the tractors.

Check the age of tractor driver---old and young. Old are careless. Young don't think quick enough.

Improve young driver training. Children should not drive tractors without training and only one should drive.

Tractors are pretty safe. Qualified drivers would help.

Hard to say. More information on tractor accidents to make farmers aware of possibility of accidents.

Roll bars would be best way to reduce accidents.

Don't know. More cautious---don't drive too long.

Don't think there are that many accidents.

Don't know of any way.

Slow tractors down for farm use and accelerate for road driving.

Less carelessness on part of operator.

Engineering problem.

Education.

No reason---it's the drivers fault, I feel.

Cut the speed down on the road and on small jobs.

Better operators.

More caution on drivers part.

Sign on back that says "Slow---Moving Vehicle."

Good common sense.

Keep the "Slow Moving Emblem" on the back when on the highway

Faulty judgment on operators part.

More careful drivers.

Use good common sense znd use safety devices.

University level---Extension service information about operating tractors.

Don't know.

No idea.

(End of submitted material)

Next on the agenda is the State of Wisconsin, Department of Administration, Mr. Harry Hatcher, State Safety Coordinator.

MR HATCHER: My position with the State of Wisconsin is to develop and coordinate a complete and continuous program for 40,000 state employees. We use this principle that no one has the right, morally or legally, to design, manufacture, sell, buy or require the use of any building, facility, equipment, material, product or process that is hazardous to the user or to the public.

The State of Wisconsin, as of May 1 this year, no longer is purchasing farm or industrial type tractors without rollover protection. We are also taking action to protect presently operated vehicles with rollover protection, safety belts, rear-view mirrors and turn signals. Where equipment is used on roads or highways, the mirror and turn signals are necessary. We have had two serious accidents with employees operating tractors, pulling loads of hay, who turned left without signaling and were hit by passing cars.

On March 31 of this year an employee of the State of Wisconsin was killed when a tractor, a front-end loader he was operating, rolled over an embankment and crushed him. Although this is the first such fatal accident to a state employee, it is a common occurrence in Wisconsin.

The State Department of Agriculture and the Divsiion of Health-Vital Statistics reports that twenty to twenty-five people are killed every year in tractor rollover accidents in our state, year after year after year. Other fatal tractor accidents take at least ten more lives every year. They also report that we have approximately 6,000 hospital emergency room cases with 2,000 of these requiring bed care because of the tractor accidents in Wisconsin.

In less than 20 years, the number of farm tractors in Wisconsin increased by 97 per cent from 127,500 to 251,000, although the number of farms decreased by 32 per cent and the size increased by 26 per cent, which means greater exposure due to increased use of each tractor.

However, farm use is only a part of the grim picture. County Highway Department employees are killed mowing steep highway lands. We have had three of those this year. Perhaps the Department of Transportation should have a corollary study on hazards of slopes designed too steeply for safe operation of these vehicles.

The State Highway Department of Illinois told me they had 60 rollovers since 1963 on such slopes. Tractor operators are killed in other work also. As the editor before me mentioned, these are gleaned only from newspaper stories. We have a difficult time getting information. This year, mostly in May and June, I have reports of 19 deaths in Wisconsin from rollover accidents; pulling trees, mowing grass, hauling fencing in a front-end loader, pulling a hay wagon, and another when the man was backing into a shed and was crushed against other equipment where the frame may have saved his life.

One startling fact, at least to us, was that half of these are children under 14 years of age. One this year was an 8-year-old boy. The tractor was driven by his 12-year-old uncle. It went into a ditch, seriously injuring one boy and killing the other.

The State of Wisconsin operates 500 tractors, on farms, in parks, in land clearing, grass cutting, trenching, logging, and many other jobs. In a survey I took of our agencies, because our Department wanted to know if we should protect all tractors, all agencies reported there is no way we can restrict the use of tractors to so-called non-hazardous situations. Their utility lies in the ability to use equipment for a wide variety of purposes.

For the State of Wisconsin this one fatal accident cost conservatively $100,000. The rollover protection for one tractor of this type costs $400. The figures come out like this:

Cost to the employing agency for one accidental death, $26,000. In filling that position the Bureau of Personnel could easily double that. If an employee had one young child, the state pays $3,762 for child support until he is 16 years old. If there are several children under five years old, this cost can be up to $30,000.

In addition, the employing agency must pay $500 to our State Fund for Dependent Children. Using these minimum figures and the formula used by the National Safety Council that administrative costs and property damage and other factors cost at least four times the medical and workmen's compensation costs, we have a conservative figure of $100,000. I know the accidental death figure the National Safety Council uses is about five times that this year.

When we go before our Board of Governmental Operations, our legislative committee that operates between sessions, to determine what funds could be allocated, we have to be pretty sure what we are talking about. Again, the cost of the protection for a tractor is about $400.

None of this, of course, takes into consideration the human and social factors, the loss to the family and the community of a father, husband and provider.

While the cause of accidents is the prime concern in developing any policy or a change in equipment or job procedures, it is not always the major reason for reaching a particular decision. Regardless of whether the accident was caused by operator error, mechanical failure, poor work methods, equipment unsuited for the job, weather conditions, or terrain difficulties--as was a big part of our problem--the indisputable fact is that the accidents and the deaths do occur.

The cause of the injury or death is a determining factor, the crushing rollover itself, as differentiated from the cause of the rollover. Consequently, we can only conclude that there is a need to protect the operator and equipment in event of upset or rollover, since it is not possible to control enough of the other factors to assure that the same type of accident and injury will not occur again. The constant, repetitive evidence is that we will have tractor upsets, unless we repeal the law of gravity, which may cause Sir Isaac Newton to roll over.

Our only answer at this time is to provide rollover protection and to include the additives of job selection, work methods, proper attachment of towed equipment, mirrors, turn signals and training of employees, concomitant where possible with close supervision. We do have that ability in some of our positions, where the individual farmer does not.

So I am here to recommend that protection such as we are discussing, the roll bar, turn signals and rear-view mirrors when the equipment is operated on the highway, be a requirement on equipment used in these jobs where there does not seem to be any other method of preventing rollover deaths.

I have one other side comment in reference to the man who preceded me when he was talking about the tractors that went in the irrigation canal. We had a woman who was in a tractor upset into an irrigation ditch this year. She was held under the water and died, where, with the protective frame, perhaps this would have given her enough space she could have gotten out. Again, as he indicated, we have too little information on all of this, in which I can concur, to give you facts that may give help in determining the total picture.

But we have enough individual instances where we think the rollover protection should be on every farm tractor, on every tractor operated on the highways, at least in the light of the way we use them in the State of Wisconsin.

CHAIRMAN HARTMAN: Thank you, Mr. Hatcher.

Next on the agenda is Mr. Anson Johnson, Rural Route No. 1, Keokuk, Iowa. Mr. Johnson.

Is Mr. Johnson here?

If not, Mr. Randt, would you be prepared to come forward?

Moving up the schedule a little bit, next on the agenda is the Farm and Industrial Equipment Institute, located in Chicago, Illinois, Mr. L. W. Randt, Safety Program Coordinator.

You have twenty minutes allowed for you, sir.

MR. RANDT: Mr. Chairman, my name is Leroy W. Randt, I am the Safety Program Coordinator of the Farm and Industrial Equipment Institute, FIEI. The 240 active member companies of the FIEI make more than 90 per cent of all of the farm and industrial equipment manufactured in the United States.

I believe that several tractor manufacturers will appear later on in this hearing to give you their views on the problem of farm safety. I would like to prepare the way for them by setting out some of the underlying facts about farm safety and what is currently being done about it.

In conjunction with the summary presented here today, we are submitting a formal treatise titled, "The State of Tractor Safety."

(The treatise referred to follows:)

THE STATE OF TRACTOR SAFETY

A Farm and Industrial Equipment Institute Presentation
to the
National Highway Safety Bureau
Department of Transportation
Pursuant to PL 91-265

Farming is a unique occupation where the home projects into the work environment, and the work environment ranges from the field to the farmstead, to the home, and on to the highway, to the urban areas, when commodities are moved to and from the farm. Daily work time inputs may range from a few hours in off seasons up to 24 hours in busy seasons.

Farm accident data has been collected in varying degrees. Kansas, Iowa and Ohio have carried on studies of accidents over a period of years. In 1968, Michigan[1] conducted a study that was comparable to accident data from the State of Ohio. Since that time, the National Safety Council has encouraged other states to make studies that will compare with the Michigan-Ohio data base.

Farming has been labeled "The Third Most Dangerous Occupation" with various conclusions being drawn from the word "dangerous". A more comprehensive study of agricultural safety is needed to add perspective to agriculture's hazard rating. The National Safety Council notes that there are 2 sources for agriculture worker counts. The Council uses a Bureau of Labor worker count which is almost 1 million workers less than the more comprehensive Department of Agriculture count. The USDA worker count reduces the fatality rate 20%.

A characteristic of the Bureau of Labor worker count is that it develops rates for the industrial populace between the starting work age of 16 and the retirement age between 60 and 65. A study of Kansas and Iowa data indicates that agricultural work fatality rates for workers between 16 and 65 years of age may be comparable to the rates in the transportation and public utilities sector.

Agriculture's retired and semi-retired workers over 65 years of age appear to develop a special safety problem substantially different from that of the retired industrial worker. Information is needed to determine if the agricultural work force between 16 and 65 years of age could be penalized for the sociological problems connected with the retired and semi-retired senior farmer.

Farm accident data includes accidents in the home, on the farm, highway, and off-the-farm. No other industry accumulates accident data or accredits accidents on this broad a base. Farm accident studies[4] at Ohio State University - 1967 and Michigan State University - 1967 - 68, show the following:

ACCIDENTS TO FARM PEOPLE

Item	Ohio	Michigan	Iowa
Place of Accident			
In home	23%	24%	23.4%
On farm, outside home	40%	49%	
Away from farm	37%	27%	
Work or Leisure Activity			
Work	50.4%	50.7%	
Leisure	44.0%	33.6%	
Injury Seriousness -- Work & Leisure			
	W & L	Work	Leisure
Slight	52%	64%	68%
Severe	45%	30%	29%
Permanent	3%	6%	2%
Fatal		0%	1%
Things Involved in Accidents to Farm People			
Autos	8.0%	6.5%	
Tractors	2.8%	6.5%	
Ladders	2.6%	6.1%	
Animals	8.0%	8.5%	
Hand Tools	8.8%	8.5%	

Progress has been made in reducing the number of fatalities to farm residents. Edwin L. Kirby,[2] Administrator Extension Service, USDA, Washington, D. C., reported in a 1970 paper titled, "Trends in the Role of Government in the Field of Farm Safety" that Wisconsin, Ohio, Nebraska, Michigan, Illinois and many other states with full-time safety specialists have had good experience in reducing farm accident fatalities. Following are examples of states with significant reductions:

		% Reduction	
Wisconsin	1946 - 146 Fatalities	58%	1968 - 65 Fatalities
Ohio	1946 - 507 Fatalities	60%	1968 - 201 Fatalities
Kansas	1946 - 75 Fatalities	32%	1968 - 51 Fatalities
New York	1949 - ---	64%	1967 ---

The National Safety Council's 1966 Edition of Accident Facts[3] stated that "Tractor accidents claim the lives of an estimated 1,000 persons annually in the United States. A rate of about 2.2 deaths per 10,000 tractors is indicated for a tractor total which has stabilized at 4,600,000 to 4,700,000 in recent years."

Various states have reported progress in reducing the number of tractor accident fatalities.

OHIO - W. E. Stuckey,[4] Leader Safety and Emergency Preparedness, Cooperative Extension Service, The Ohio State University, L-58, "Tractor Tragedy, Will you be a Victim?", published May 1968. -- "During the years 1956-60 fatalities averaged 43 per year, compared to an average of 35 fatalities per year from 1961-67." (WHEN COMPARED TO THE 1956-1960 PERIOD THIS REPRESENTS A 19% IMPROVEMENT.)

MICHIGAN - R. G. Pfister,[5] Extension Safety Engineer, Agricultural Engineering Department, Cooperative Extension Service, Michigan State University, File No. 18.48, Information Series 228, "Fatal Farm Tractor Accidents 1955-1967," published March 1968. -- "Michigan farmers have a lower fatal accident rate than most states and it is improving. Over the last five years (1962-1967), Michigan's yearly rate has averaged 19 deaths per 100,000 tractors." (WHEN COMPARED TO THE 1955-1959 PERIOD THIS REPRESENTS A 20% IMPROVEMENT.)

A review of tractor accident fatalities in 1969 in important agricultural states shows that there is a continuing trend to reduce tractor fatalities below the 2.2 per 10,000 tractors recorded by the National Safety Council[3] in its 1966 Accident Facts.

State	Tractor Fatalities 1969	Estimated Tractor Population	Fatality Rate Per 10,000 Tractors - 1969	Fatality Rate Per 10,000 Motor Vehicles 1969 (NSC)
[6] Ohio	34	198,000	1.72	5.8
[7] Minnesota	44	282,000	1.56	4.3
Wisconsin	43	246,700	1.74	5.3
[8] Nebraska	29	180,000	1.61	4.4
Iowa	56	327,000	1.71	4.3
[9] Kansas	22	174,300	1.26	4.9
	Total -	1,234,200	Av. --1.60	Av. --4.83

The registration death rates for motor-vehicles in 1969 are included to show that tractors have approximately one-third the registration death rate of motor vehicles. Implement & Tractor[10] magazine estimates that there were 4,800,000 tractors on United States farms in 1969. Using the rate of 1.60 fatalities per 10,000 tractors developed from the population of 1,234,200 tractors or 26% of the tractor population we project 768 fatalities for 1969. This is a 23% reduction from the National Safety Council 1965 projection of 1,000 fatalities, and represents a continued decline in tractor fatalities as noted by Pfister and Stuckey in their mid-1960 reports.

Agriculture has mechanized at an extraordinary rate during the last decade. Farmers own[11] 6.6 million cars and trucks which are involved in 3,500 fatalities or one fatality for each 1,900 vehicles. Farmers own[10] 4.8 million tractors which are involved in 800 fatalities or one fatality for each 6,000 tractors. In addition to these 11.4 million cars, trucks and tractors, there are probably another 20 million other machines of various types on American farms. These cause approximately[12] 250 fatalities or one fatality per 80,000 machines. The farm tractor works in association with most of the 20 million farm machines in the miscellaneous machine pool. In each case the tractor-machine combination represents a different mechanical combination and accident exposure system.

The farm resident accident profile for 1969, as compiled by the National Safety Council, shows a total of 6,900 fatalities to farm residents. This is about 7% less than 1968. Agriculture's accidents are classified by the National Safety Council into four categories. The following NSC tabulation with machine and motor vehicle relationships will establish a perspective for the tractor - machine motor vehicle pool used by the American farmers.

Fatality Rate		Deaths	Disabling Injuries	Farm-Owned Machines
	TOTAL	6,900	600,000	31,400,000
5.3%	MOTOR VEHICLE	3,500	130,000	6,600,000 Cars & Trucks
	WORK			
1.6%	In Farm Work (Includes estimated 800 tractor fatalities)	1,800	170,000	4,800,000 Tractors 20,000,000 Miscellaneous Machines
	In Non-Farm Work Off Farm	200	30,000	
	HOME	1,300	200,000	
	PUBLIC NON-MOTOR VEHICLE	750	90,000	

There are limits to, and some variance in, the statistics available on the location, rate and severity of agricultural tractor accidents. This has long concerned the manufacturers of agricultural tractors. The data ranges from excellent - from those states with agricultural safety specialists, to minimal from states with low fatalities or no significant agricultural safety programs. The agricultural fatality record speaks to some progress. Safety technology has been improved and safety measures are being incorporated to maintain a rate of improvement. Representatives of FIEI companies have participated in programs to retrieve and catalog data pertinent to agricultural tractor accidents.

The industry has utilized research work from safety specialists working in the major agricultural states to further define the major characteristics of fatal agricultural tractor accidents. The findings of this research work have resulted in new standards being developed, more automatic provisioning of safety devices, and new developments which reflect our society's and industry's concern for the welfare and safety of the farm family. A more comprehensive knowledge of the location and types of agricultural tractor accidents has contributed to safety progress with newer generation tractors. An understanding of operator characteristics has generated educational programs which will contribute to the reduction of fatalities. The following data reflects certain patterns concerning agricultural tractor accidents:

Location of Fatal Agricultural Tractor Accidents

[5] Michigan 1960-67	[6]Ohio 1963-69	[13]Iowa 1947-64	Estimated 1969 48 State Projection
57% - Field	59% - Field	66% - Farm	57% - 456 Fatalities
9% - Farmyard	11% - Farmyard		10% - 80 Fatalities
29% - Public Roads	21% - Highway	33% - Highway	28% - 224 Fatalities

Out of 800 projected fatalities, approximately 456 occur in the field, 80 in the farmyard and 224 on the highway.

Types of Fatal Agricultural Tractor Accidents

[5] Michigan 1955-67	[6]Ohio 1963-69	[13]Iowa 1947-64
60% - Overturns	65% - Overturns	58% - Overturns
Road Accidents	Road Accidents	[14]Road Accidents 1949-66
47% - Collision		29% - Collision
21% - Ran off Roadway		58% - Ran off Roadway
32% - Other		13% - Other

The variance between states in the data on the characteristics of tractor accidents on public roads can be accounted for by the difference in road building practices. Iowa has comprehensive studies of its highway tractor accidents. In a tabulation on the 1949-1966 period Iowa shows that "motor-vehicle accidents with tractors result in relatively low fatality, only 2%." Even though tractor density and highway traffic density have increased, Iowa has reduced its tractor-on-highway accident rate by one-fourth from 1950 to 1966. This improvement has been brought about by driver education, better lighting, use of Slow-Moving-Vehicle emblems and the relocation of drivers from the extreme rear of the tractor. The Iowa highway history is as follows:

[14] Number of Tractor Accidents on Iowa Roads

	1950	1955	1960	1966
Tractors	224,098	297,060	325,564	332,673
Accidents	274	274	316	310
Rate/1,000 Tractors	12.2	9.2	9.7	9.0
Collision Accidents	240	244	271	251
Fatalities	24	19	20	26

Farm machinery and tractor safety on the highway has benefited from the adoption of Slow-Moving-Vehicle emblems in 26 states. The National Safety Council[15] reported the following progress in the July-August 1969 issue of Farm Safety Review:

> "Nebraska: In 1965, there were 170 such (car-tractor) collisions on Nebraska roads. The number dropped to 145 in 1968. Down 15%) Deaths (in car-tractor collisions) went down from 11 in 1965 to 6 in 1968--a 40% reduction."
>
> "Michigan: There has been a big reduction (47%) in non-intersection rear end collisions with slow-moving vehicles since the invocation of the SMV emblem law. Fatalities dropped from 4 in 1966 to zero in 1968."

The ASAE Standard S279.4 to provide specifications for Lighting and Marking of Agricultural Equipment and Industrial Equipment on Highways was first released in 1964. In 1969 it was revised to provide much superior highway identification, including one SMV emblem. The 26 states that have legislation regarding the use of the SMV emblem are as follows:

California
Florida
Georgia
Idaho
Indiana
Iowa
Illinois
Kentucky
Maryland
Michigan
Minnesota
Montana
Nebraska
New Mexico
New York
North Dakota
Ohio
Oklahoma
Oregon
Rhode Island
South Dakota
Texas
Vermont
Virginia
Washington
Wisconsin

The tractor industry has participated in the voluntary development of 13 standards and one recommendation for tractor safety on the highways. There are seven standards and three recommendations pertaining to operator safety. There are three standards and three recommendations for Power-Take-Off safety. Four standards pertaining to hitching safety and two recommendations for general safety matters.

The industry has been deeply concerned with tractor overturning accidents. It participated in research to define the problem and started its standards development program in 1966. Standards pertaining to protective frames and enclosures were published in 1967. These were revised in February 1970. Tractor cabs or protective enclosures and frames are phasing into the market place at an increasing rate. Protective enclosures are on an adoptive cycle and the number of units installed on tractors is expected to increase steadily over the next five years.

The protective enclosure art has progressed far beyond providing protection in case of tractor roll-over. Enclosures are available to protect the operator from dust, noise, heat and vibration. The cost of these more sophisticated enclosure systems can be high. Most farmers are already making a considerable investment in safety devices such as power steering, power-lifts, and power-shifting mechanisms to allow the farm family to participate in the farming operation and the added financial burden of the new enclosure system is a serious consideration in the provisioning problem. The substantial capital requirements in farming necessitate capital equipment budgeting. This budgeting is a major consideration in the provisioning rate for protective enclosures.

Protective enclosures offer considerable protection to the operator who forgets to wear the seat belt. Seat belt education will probably be more difficult because of the need for the farm operator to move about in order to watch the machines connected to the tractor. There are, however, some agricultural operations such as material handling in barns or low buildings and orchards where protective enclosures would seriously compromise the work capabilities of the tractor.

Data is available on tractor overturns from short term, long term, and random studies. The following summaries develop patterns:

Fatalities - Short Term Tractor Overturn Statistics

[16]Nebraska - 1969

Overturns - 69%*
Sideways OT 85%
Rear OT 15%

[6]Ohio - 1969

Overturns - 62%*
Sideways OT 65%
Rear OT 30%

[7]Minnesota - 1969

Overturns - 43%*

[17]Wisconsin - 1968

Overturns - 53%*

[9]Kansas - 1969

Overturns - 59%*

*Quoted as a percent of tractor fatalities from all causes.

Fatalities - Long Term Tractor Overturn Statistics

[5]Michigan 1955-67

Overturns - 60%*

[6]Ohio 1956-69

Overturns - 65%*
Sideways OT 65%
Rear OT 30%
Forward OT 4%

[13]Iowa 1947-67

Overturns - 58%*
Sideways OT 98%
Rear OT 1.5%

[9]Kansas 1965-69

Overturns - 52%*

*Quoted as a percent of tractor fatalities from all causes.

Non-Fatals & Fatalities - Random Tractor Overturn Statistics

[18]Indiana 1968-69

(Willsey-Liljedahl)

145 Accidents (All non-fatal)
Sideways OT 83%
Rear OT 14%
Forward OT 3%

[19]Nebraska 1966-69

(R. Schnieder)

100 Accidents (42% Fatal)
Sideways OT 86% (65% - 180°)

R. Schnieder[19] Safety Specialist, Nebraska Cooperative Extension Service reports, "The leading cause of accidents in this study seemed to be improper operation of the tractor and equipment, which included excessive speed, chasing cattle, carelessness and losing control of the tractor. This occurred in 43.9% of the accidents. Inexperience and operating the tractor on an incline accounted for 21.3% of the suspected causes."

Willsey and Liljedahl[18] report that overturning was heavily associated with tractors over eight years old. "Of the 145 tractors involved in this study, 27 (18.6%) were 1960 or newer models, but only three of the 37 loader equipped tractors (8.1%) were in this age category." They report 14 different tractor-implement combinations involved in their study of 145 overturning accidents.

A detailed study of tractor accidents in Ohio shows that in 1968 one-third of the fatal tractor accidents occurred with persons over 65 years of age. The oldest was 83. These over-65-years-old persons accounted for 38% of the overturning accidents in 1968. In 1969, these over-65-year-old tractor operators accounted for 27% of the tractor fatalities and 33% of the overturning accidents. The Ohio studies also show that old model tractors are heavily involved in overturning accidents.

The combination of the elderly driver, old model tractors, a wide range of implements and improper operation of the tractor and equipment contribute significantly to the tractor overturn problem.

A 1947-1964 Iowa Fatal Accident Study[13] shows that 34% of the fatalities happen to persons over 65 years of age. A 1946-68 Ohio Farm Fatality study shows that 40% of the fatalities happen to persons over 65 years of age. A provisional study of accidental deaths in Minnesota in 1969 shows that 32% of agricultural work deaths happen to persons over 65 years of age. This is a direct contrast to other industries such as construction, manufacturing, transportation and public utilities with formal retirement programs, starting at age 60. If one-third of agriculture's work and machinery fatalities should be eliminated by work retirement programs for persons over 65 years of age, agriculture's work accident death rate would be comparable with that of transportation and public utilities.

Formal tractor operator training has been conducted for many years under 4-H and Vocational Agriculture programs. This has been accelerated in the past few years. Dr. N. J. Wardle, Extension Agricultural Engineer, Farm Safety, Iowa State University, reports that in 1969 his department conducted 240 machinery operator schools and trained 7,589 youths. In 1970, they have trained 249 instructors and expect to have schools in all counties. A followup of these trained youth in agriculture shows that the educational input has significantly reduced tractor accidents. A Nebraska study showed that none of 854 youths trained in safe tractor operations were involved in serious tractor accidents.

Safety education has played an important part in maintaining a progress in the reduction of agricultural tractor accidents. The safety education teams in Ohio, Minnesota, Wisconsin, Nebraska, Iowa and Kansas which generated the 1.6 fatality rate per 10,000 tractors in comparison with the 1965 2.2 average fatality rate can be credited with saving 69 lives per year in tractor accidents alone. Since these state safety teams work over the entire safety spectrum they must be credited with more than the 69 lives per year mentioned. This leadership role in farm safety education is assigned to the Extension Service of USDA by the Secretary of Agriculture's Memorandum No. 1364[2]. It states that the "Federal Extension Service in cooperation with the State Extension Services shall be responsible for effectuating a program for the safety of farm people in their life and work on the farm." In view of the remarakble life payout in those states with active safety departments, it is recommended that the successful safety programs be substantially expanded to more states. Safety education is a particularly effective and necessary tool in saving lives.

The Farm and Industrial Equipment Institute has, since 1957, supported safety education programs in tractor and harvest machinery safety. These programs, sponsored through the FFA chapters, have each year created a special focus on important farm safety problems. FIEI has also cooperated with the American Association of Agricultural Engineering and Vocational Agriculture in developing the comprehensive texts and teaching aids in the area of Agricultural Mechanization. Twenty states, representing 67% of the vocational agricultural teachers in the United States, use these materials.

Power-take-off accidents are part of the tractor-machine subsystem and thus indirectly related to tractor safety per se. The tractor is involved in the PTO accident only because it has a power stub-shaft with associated controls to engage and disengage the power flow through the shaft. This tractor stub-shaft by itself is rarely involved in an accident. It is the articulated power transmission shaft between the tractor and the driven machine that is generally involved in the PTO accident. The maintenance of this intermediate shaft is taken care of in conjunction with the driven machine since it is considered to be a part of that machine. Knapp[20] reported in his 1962 PTO study that in 61% of the accidents investigated, "one or all of the manufacturer's available shields were missing."

Information on fatalities from power-take-off entanglement is limited. These fatalities tend to be included in "catch-all" categories. The power-take-off system has been and is under continuous consideration in the industry's standard making bodies. The standards were last revised in 1969. Power-take-off accidents should continue to decline as a result of the definite trend to more self-contained machines.

Tractor mounted corn picker accidents have been dramatically reduced through the transfer of corn picker heads from tractors to combines. The ability of the combine to process excessive stalkage and the new, low profile corn heads designed for combine use have reduced header stoppage and the attendant clearing to a very low level.

Safety improvements have been zealously incorporated into each generation of tractors. Since 1955 new tractor technology has phased into the market on a five year basis. This has brought larger tractors with more sophisticated and safer mechanical systems into agriculture. These newer tractors show a low involvement in tractor fatality histories. In point of time they will reduce tractor fatalities as older machines are phased out.

A separate summary is attached as an addenda to this paper.

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(End of submitted material.)

The Farm and Industrial Equipment Institute has endeavored to document the deliberate progress that has been made in agricultural safety. We want to make a special note that this progress has come about as the result of cooperation between FIEI and its members, the National Safety Council, the Extension Service of the U. S. Department of Agriculture, and the Extension Services of the various states, the U. S. Department of Labor, the National Institute for Farm Safety, technical societies such as the American Society of Agricultural Engineers and the Society of Automotive Engineers, and the cooperating farmer organizations such as the American Farm Bureau and last, but not least, the farmer himself.

First, I would like to take a moment to discuss what we know about the rate of accidents associated with farming. Our information about farm accidents comes mainly from statistics gathered by the National Safety Council and from studies conducted by a handful of states with active state safety departments. A more complete analysis of the data from these sources is contained in my written paper.

Farming is the only activity where farm, farmstaed, home and highway are all part of a single environment, and much of our accident information lumps together all injuries happening to farmers. No other occupation that I know of is treated in this way. However, only about half of the farm residents' accidents really relate to farming as an occupation, that is, injuries associated with farm work tasks. Injury seriousness at work and leisure is quite similar. Almost two thirds of the work and leisure injuries are slight in nature.

Detailed information on the number of work-oriented farming fatalities is quite poor. The National Safety Council has used a figure of 2, 500 deaths per year. This is recognized as an estimate and it may be high. Data from Iowa and Kansas suggests a much lower farm worker fatality rate.

An accurate statement of injury rates requires a correct count of the workers involved. The National Safety Council notes that there are two sources for agricultural worker counts. The Council uses a Bureau of Labor worker count which is almost one million workers less than the more comprehensive Department of Agriculture count. If you use this lower and, we think, less accurate count, the fatality rate tends to become overstated.

A characteristic of the Bureau of Labor's worker count is that it develops rates for the industrial populace between the starting work age of 16 and the retirement age of between 60 and 65. A study of Kansas and Iowa data indicates that in agriculture old workers, who would not even be part of the sample for other industries, account for a disproportionate share of injuries in agriculture.

Recent data refined out of sampling studies show that of the injuries which are attributable to farming as an occupation, only a small per cent are related to tractors. Autos, animals and hand tools all have a higher frequency for the farmer than does the tractor. Ladders and tractors have about the same accident frequency.

The National Safety Council's 1966 edition of "Accident Facts" estimated that tractor accidents claimed the lives of about one thousand persons annually in the United States and that this represented a rate of 2. 2 deaths per 10, 000 tractors. More recent data from six states, Ohio, Minnesota, Wisconsin, Nebraska, Iowa, and Kansas, indicate that the current fatality rate is lower, perhaps about 1. 6 deaths per 10, 000 tractors.

A better estimate of the current rate may be about 800 fatalities per year.

Of the machines farmers use, automobiles and trucks are involved in many more fatalities than farm tractors and implements. Farmers own approximately 31,000,000 machines of all kinds. They have 6.6 million cars and trucks involved in 3,500 fatalities or one fatality for each 1,900 vehicles. Farmers have 4.8 million tractors which, as I have said, are involved in 800 fatalities. This is one fatality for each 6,000 tractors. Two hundred and fifty fatalities are spread over another 20 million other machines of various types which farmers own, or one fatality per 80,000 machines. The contribution of any one of these other machines to the over-all farm injury picture is relatively low.

It also appears that farming is becoming a safer occupation. I have already suggested that while in 1966 the National Safety Council estimated a fatality rate of about 2.2 deaths per 10,000 tractors, 1969 data from 6 agricultural states suggests a current rate closer to 1.6. These 6 states account for 26 per cent of the tractor population.

A study in Ohio showed 19 per cent fewer deaths per year in the period 1961-'67 than there were in 1956-'60. A similar study in Michigan showed a 20 per cent improvement, measured in deaths per 100,000 tractors, in the 1962-'67 period as compared with the 1955-'59 period. The states of Wisconsin, Ohio, and New York reported reductions in over-all farm accident fatalities of about 60 per cent from the middle 1940's to the present. Kansas reported a 32 per cent improvement for the same period. Nebraska reported deaths from highway tractor accidents down 40 per cent from 1965 to 1968 and collisions down 15 per cent from 1965 to 1968.

These facts indicate a continuing and significant improvement, and they are recited here more for the purpose of showing the progress that has been made and the hope that we have that the things we are doing will further reduce this accident rate in the future.

It is not surprising that the states like Iowa, Michigan, Nebraska, and Ohio, with some of the best statistical data, are also those with the most extensive safety education programs. This may be a good place for me to emphasize our industry's conviction that the greatest potential for further improving farm safety lies in better safety practices by farmers and better programs for safety education and training.

R. Schneider, safety specialist, Nebraska Cooperative Extension Service, concludes, in a study of tractor overturns, and I quote, "The leading cause of accidents in this study seems to be improper operation of the tractor and equipment, which included excessive speed, chasing cattle, carelessness, and losing control of the tractor. This occurred in 43.9 per cent of the accidents. Inexperience and operating the tractor on an incline accounted for 21.3 per cent of the suspected causes." That is the end of the quote.

Formal operator training has been conducted for many years under 4-H and Vocational Agriculture programs. This has been accelerated in the past few years, particularly with the help of the Department of Labor. Dr. N. J. Wardle, then extension agricultural engineer, farm safety, Iowa State University, reported that in 1969 his department conducted 240 machinery operator schools and trained 7,589 youths. He indicates that a follow-up of these graduate youths in agriculture show that the educational input significantly reduced tractor accidents in those age brackets.

For 1970, Iowa has trained 249 instructors and expects to have schools in all counties. A recent Nebraska study showed that none of 854 youths trained in safe tractor operation were involved in serious tractor accidents.

I might add that our industry through the FIEI has provided support for safety education programs in tractor and harvest machine safety conducted by Future Farmers of America chapters. FIEI has also cooperated with the American Association of Agricultural Engineering and Vocational Agriculture in developing comprehensive texts and teaching aids in the area of machinery operation, maintenance and safety. Twenty states representing 67 per cent of the Vocational Agriculture teachers in the United States use these materials.

While the contribution education makes to tractor safety cannot be measured with precision, it is impossible to escape the conclusion that it is extremely significant.

I would like now to discuss the kinds of accidents in which farm tractors may be involved. Estimates from the states which have the best records indicate that from 50 to 60 per cent of tractor fatalities occur in the field, about 30 per cent occur on the highway and the remainder occur in the farmyard. In highway accidents two causes, collisions and running off the roadway, account for most of the accidents. It is interesting that there appears to be a great variation between states in the frequency of tractors running off the roadway. This suggests that the design of roads and roadways might be an area which has considerable potential in improving safety.

The main contribution which machinery design can make to preventing highway accidents is to light and mark them in such a way as to minimize the danger of cars or trucks running into them and crowding them off the road. An important part of this problem is to warn the motorist that he is approaching a slow-moving vehicle. The tractor industry has taken the lead in developing standards for doing this, including lighting systems and the now familiar triangular slow-moving-vehicle emblem. It has worked closely with those state legislatures which have incorporated this kind of marking into their highway laws and the sponsors of the Uniform Vehicle Code. The SMV emblem has been incorporated into legislation in 26 states. The industry has adopted 13 standards relating to the safety of tractors on the highway and is currently developing more.

About 60 per cent of the tractor fatalities occur with overturning tractors. The industry has made great progress in making tractors less susceptible to overturns, including improved stability, better hitching, ballasting, and other developments. Overturn protection can also be provided by a protective frame, or by a cab so designed as to stand the forces involved in an overturn. Satisfactory equipment is now available in either of these forms, and the industry has adopted standards for the structural integrity of overturn protective devices.

It must be recognized that the overturn protective devices introduce quite significant cost increase into the machine, whether provided through a separate protective frame or by incorporating the necessary strength into a cab. Overturn protection is offered to customers on an optional basis, and significant efforts have been made to promote their purchase and use by customers. We find that more and more of the farmers are accepting this education and more and more tractors are being equipped with cabs. We hope that this trend will result in more and more tractors being equipped with overturn protection. We should remember, though, that any market situation has an adoptive cycle and that progress is somewhat relative to that pattern.

I should also mention that overturn protection can interfere with some operations or have other disadvantages to the farmer such as material handling in low farm buildings and operation in orchards.

Highway accidents and tractor overturns account for approximately 90 per cent of all fatalities. This is not to say, however, that the farm equipment industry has ignored other safety problems. On the contrary, to the extent that injury potential can be reduced by changes in machine design, we think the industry continues to be energetic and effective in the pursuit of safety. The commitment of individual companies to safety engineering is high. Through ASAE and SAE, 36 industry standards related to safety have been adopted. Important efforts to devise new or improved standards are in process.

I would now like to say a word about power take-off accidents which in the past have been a source of injury that has caused concern. Power take-off accidents are part of the tractor-machine subsystem. The tractor itself is involved in the PTO accident only because it has a power stub-shaft with associated controls to engage and disengage the power flow through the shaft. The tractor stub-shaft by itself is rarely involved in an accident. It is the power transmission coupling between the tractor and the driven machine that is generally involved in the PTO accident.

The power take-off system has been and is under continuous consideration in the industry standards program. A great deal of work has been done on devising suitable shielding. One of the important problems is the removal of this shielding from the machine either because it has been damaged or the operator sees no need to keep it in place. A 1962 PTO study reported that the shielding had been left off in 61 per cent of the accidents investigated. Shielding has subsequently been developed which goes a long way towards solving this problem. In addition, shielding now being used provides a more complete shielding of the coupling. We believe that the potential for PTO injuries has been substantially reduced in machines now being produced. Efforts are still being expended to master all aspects of the PTO problem and still more improvement is expected.

The tractor industry has been consistent in developing and updating safety standards. 1970 production tractors incorporate new levels of safety, including environmental protection. The farmer, in relation to other sectors and other income levels, is investing heavily in safety-oriented devices. Much of the tractor safety problem is related to older machines, elderly operators and children in the work environment.

We would like to have you know that there is at work in agriculture today a safety system of all of these agencies that we mentioned that is steadily reducing tractor accidents.

Thank you, Mr. Chairman, for this opportunity to assess and speak for agricultural machinery safety programs.

CHAIRMAN HARTMAN: Thank you, Mr. Randt.

Is Mr. Anson Johnson here?

We are sorry about this. He is a farmer who wrote and said he would like very much to attend this meeting.

We are on schedule. Before rigor mortis sets in later on, why don't we take a ten-minute break. I am looking at a clock that most of you can't see, but I see it and it says 10:30 on the nose. At 10:40 on the nose, we shall start again.

(Short recess.)

CHAIRMAN HARTMAN: With your permission, I might take a little liberty to deviate from the agenda since Mr. Johnson is not here. Mr. G. W. Steinbruegge from the faculty of the University of Nebraska would like to talk a very short time on test procedures, basically the overturn tractor test procedures.

Mr. Steinbruegge, will you come forward and give your name, your title, and so on. If you will limit your remarks to five minutes, as we discussed, I would appreciate it.

MR. STEINBRUEGGE: Mr. Chairman, Ladies and Gentlemen:

I am George Steinbruegge, from the University of Nebraska. I am associated with the university's and the State of Nebraska's tractor testing program. I imagine that many of you in this room are acquainted with this program. We test tractors and the information which we get from these tests is available to anyone who wants to write and get the information.

The reason we test is because we have a state law which requires that a tractor be tested and passed upon by a board of engineers at the University in order to receive a permit to sell the tractor in that state. We do the testing and we give the results to our State Department of Agriculture, who are the ones who issue these permits.

The tests which we do are performance tests and the criteria of the tests is really set up by the manufacturer himself. If the manufacturer, for instance, says that the tractor has 50 horsepower on the drawbar, then we test it and see if it does have 50 horsepower on the drawbar. If it does, at least this bill will not keep the manufacturer from receiving a permit to sell. If it does not, we do not recommend that it receive a permit to sell.

Our tests so far have been performance tests related to things like horsepower and torque and wheel slip and so forth. But a few years ago when it became evident that safety was going to be a factor in selling tractors, we felt that there might be a manufacturer who would begin to claim that his tractor met certain safety standards. A liberal interpretation of our law would be that we would have to test to see if it meets this standard, if they make such a claim. Therefore, we set out about four years ago to acquaint ourselves with tipping tractors over, and we have done this, you know, in a limited way. I expect we have probably tipped over twenty-five tractors with rollbars on them or cabs and we have learned something which we feel should be presented to the Committee that is holding this meeting today.

We have tipped tractors over on flat surfaces, on into ditches and we have used this Swedish pendulum test, which is a part of the safety standards recognized by ASAE and SAE and FIEI which Mr. Randt was referring to. We wanted to see just how present cabs and rollbars might fit this standard.

We have found that our tests show this standard to be inadequate, that the forces and the deflections which cabs and rollbars may be expected to withstand are much greater than the forces and the deflections which the cab may have to withstand if it was being tested according to these standards.

We have found in several cases that the deflections of the cab under an actual test will be three to three and a half times greater than the deflection which that cab would undergo if it was tested according to the standard.

Therefore, my purpose here today is to bring this out because I feel that there probably are not too many in this room, other than company representatives, who are actually acquainted with the results of this standard. Therefore, I ask that this Committee holding this meeting be careful about just accepting the present standard in total. I would suggest that they attempt to write a new standard based on more complete research and with representatives of the public on the standard-writing committee.

Thank you.

CHAIRMAN HARTMAN: Thank you, Mr. Steinbruegge.

Next on the agenda is Allis-Chalmers, Milwaukee, Mr. Owen R. Davis, Manager of Engineering, Tractor Engineering Department, Agricultural Equipment Division.

Would Mr. Davis please come forward. You will note that we have given you fifteen minutes.

MR. DAVIS: Mr. Chairman, Ladies and Gentlemen:

I would like to talk to you first as an engineer and express some of my thoughts on the subject of tractor safety.

Mr. Roy Randt has already mentioned all of the farm tractor standards established within the industry, many of which are related to tractor safety. He has also presented the statistical record of farm accidents and how the tractor has been involved. I don't think the exact figures are pertinent to the points I want to make, but I think it is significant to note the common ladder is running neck and neck with the tractor for involvement in farm accidents as reported in several of the surveys I have read.

I also think it is significant to note that we have a much better record in farm tractor safety than do our cousins in the automotive industry, and they even have an advantage over us because someone was thoughtful enough to provide some degree of operator standardization for them through operator training and age limitations.

Did you ever stop to think how the record might be without the tractors? Total hours of exposure per year is certainly lower than it would be without tractors, but without records all we can say for sure is that the whole standard of living, the rate of growth, and the economy would be different. Some of us might be starving. I like to think, in fact I am sure, we are better off the way it is today, but I know also the job isn't finished.

For a guide in formulating policies and stimulating further progress, we must consult history. How did we accomplish all of the progress up to the present modern-day tractors?

The standards and safety device innovations existing within the industry represent a lot of personal hard work by dedicated individual engineers working together in the industry. I feel we have accomplishments to be proud of.

Of the many engineers I know in this industry, all are well aware of their responsibilities toward product safety. Liability actions are, of course, contributing some of this awareness lately.

The leveling off of accidents and severity rates speaks loudly for the accomplishments within our engineering efforts. Right now the attitude among the engineers is one of challenge, one of how can we improve the utility and desirability of the safety devices to the extent that our customers want them and want them enough to pay for them. There is also a challenge to reduce the costs of safety devices to the extent that they are an insignificant part of the tractor cost, and, therefore, easily sold on safety merits alone. I think this attitude is a much better path of action, by the way, than the examples set for us by the automotive industry, particularly as concerns the seat belts which were legislated, but the public has not been sold entirely on their use to this date.

Generally speaking, I believe that legislative regulations tend to stifle the challenge of innovation. Laws regulating the design make the lazy engineer's job even easier because someone else has designed the product to some degree and his only job then becomes one of compliance to the regulation.

Under our present voluntary system, engineers learn to work together and innovation is stimulated, rather than stifled, by the mere fact that engineers compete with one another in the efforts to obtain the best design possible for safety, reliability, performance, value, and other criteria of good design. If particular designs are required by law, the emphasis will probably shift toward how to satisfy the letter of the legal requirements with as little cost as possible. Also, I'm afraid much attention would tend to be devoted to proof of compliance with the letter of the law.

Protective frames, of course, are one example where the safety device is available but not currently in widespread use. I can think of several main actions which are currently taking place to stimulate the interest and improve the acceptance of the protective frames:

One is the provision of safety cabs for rollover protection. The customer will be more likely to use this device when it is available from all manufacturers because the rollover protection cab will also offer other features such as sound attenuation, improved comfort, and protection from the elements. This way, our customer, the farmer, is encouraged to use the safety device through other means besides just a legislated regulation.

I, of course, would recommend the use of rollover protection devices on current tractors. I am a firm proponent of safety devices and even wear the seat belt in my automobile. I also drive a heavy automobile because statistics have shown that use of the heavier automobile offers better protection for the auto occupants in case of collision than do many of the compacts which are more and more prevalent on the highways today. Yet, I see no attempt toward regulation of the size and weight of the automobile. Why? Because a regulation of this type would be a gross attack on the freedom of choice currently enjoyed, to some extent, by John Q. Public and because the corresponding high costs would put the necessary automobile out of economic reach of most people.

Could a similar effect be caused by regulating safety devices on tractors and, thereby, causing large price increases? Could it cause some farmers to continue using old tractors already considered unsafe by today's standards just because he can't pay or stubbornly resists the regulated devices? Might the farmer find himself under a protective frame provided by law but refuse to wear the seat belt and, thereby, be in a more hazardous situation?

In the outline which I turned in to the Department of Transportation, I promised a "peek" at future designs. What are the designs that are on the drawing boards for future tractors? I think it is safe to say without divulging company secrets, that tractors in the future will offer better sound protection. Sound pressure levels will be no greater than one-quarter of the present tractor noise levels. Operator protection from rollover accidents will virtually become standard equipment except for applications where their use would seriously impair function. There will be a greater thrust towards standardization of lever actions and other controls. Operator stations will become more and more vibration free and I believe that there will be significant efforts put toward the isolation of the operator from road- and hazard-induced shocks.

There will be power trains available in the near future offering an infinite number of speed ratios, all controlled with a single lever. Considerable attention will be directed toward the versatility of the tractors giving greater and greater tread capability in both the front and rear axles. I think there will be more and more use of four-wheel-drive tractors. The horsepower race will continue and provide a more and more useful tractor to keep the farmer in the field for less and less hours, and, therefore, reduce the fatigue-generated accidents. There will be increased uses in hydraulically operated devices to reduce the work load of the farmer. All of these new design features will result in safer tractors, either as a by-product of the main design or as the major effort toward which the designs are directed. Engineers will continue to use their knowledge for advancement of human welfare. They will continue using technology to provide better and better choices for the farmer to make if he is left free to make choices.

I believe manufacturers in general could have about the same opinion and viewpoint toward safety as those which I have expressed as an engineer.

The free enterprise system and the competition among companies has been largely responsible for the American way of living and, in fact, the cost of living, if you will. We all know that we live well and that we are reasonably well protected from safety hazards, due in large part to the innovation that has been stimulated by the competitive spirit between the companies.

Everyone within the industry can be equal on legislated items; therefore, reducing the competition and the incentive to be better in every way, including safety. If the responsibility to the customer is assumed by government agencies on those items under legislation, it might cause the manufacturer to be somewhat more of a disinterested, law-abiding bystander than he is at the present time.

Allis-Chalmers, like most large companies, has a corporate policy on safety and on the safety of our products. Some of it reads as follows:

> "It is the policy of the company to have an effective industrial accident prevention program in all phases of its operations, and to provide customers with safety-engineered products by utilizing the principles of safety engineering and safety education. Safety, when integrated into all functions, operations, and products of the company, contributes to economic success, product acceptability, and the well-being of our employees, customers, and the community. Safety is not achieved automatically. Consistent and progressive endeavor is required for high safety achievement."

We do have a great concern for the safety of our customers and believe in doing everything we can to build safe products within the competitive standards of the industry.

We believe that the current process of voluntary standards within the farm equipment industry has produced optimum results and we definitely think this method of standardization should be continued. In this voluntary standards effort, we are reasonably well assured that the standards which are set will be appropriate since the best experts within the industry are called upon to contribute to these standards developments.

However, there are areas of participation in which some government action could be of great assistance to the industry in providing better safety on farm tractors.

First, it seems the government could provide funds for gathering of statistics for accident reporting. These statistics, when gathered on a greater coverage than what is currently available, would assist the industry leaders in providing the safety devices which would do the most good in protecting operators from accident hazards.

Secondly, assistance in conducting educational programs would also be a logical area for the federal government's participation.

Thirdly, consider how FTC rulings might be altered to allow closer cooperation between companies, possibly with some supervision, in matters of safety device standardization.

Fourthly, in the event that very costly safety devices are required by law on farm tractors, it might be wise for the government to consider subsidizing these devices in the onset of standard protection to alleviate the economic load on the American farmers.

We feel the farmer who uses the tractors should have the largest voice in such matters and we feel he should equip his tractor with a protective frame if he so chooses.

Allis-Chalmers wishes to express a willingness to cooperate and a desire to take part in the formulation of federal regulations if they are required.

The utility, versatility, quality, reliability, and safety provisions in modern farm tractors are subjects which must be thoroughly studied before any standards are adopted for safety devices on tractors. Variations in requirements often affect the design of the tractors. These variations must be understood by those proposing to draft regulations or standards applied to tractors. Perhaps it would be wise to commission a panel of experts from the industry to advise the legislators.

The ability to adapt to changes in performance requirements between jobs is another major consideration in the design. The easier it is made for the operator to adjust the tractor or change the configuration in order to do a certain job, the more likely the tractor is going to be properly prepared for the job to be performed. It is, therefore, likely to be operated safely on the new job.

For this reason, the rollshift front axle has been provided on Allis-Chalmers tractors to avoid the necessity of jacking the tractor up to make front wheel tread adjustments. Also, a first with Allis-Chalmers was the power-adjusted rear wheels which enable the operator to adjust the tread of the rear wheels from the tractor seat using the power of the engine.

The ability to quick-couple the hydraulic attachments for rear-mounted implements is another feature making a tractor easily adaptable to changing implements and changing job performance. Various devices have also been provided over the years for making the hitch easier to attach to the implements. For instance, Allis-Chalmers tractors provide an extendable lower link which can be articulated at the end of the draft arm and make hitching to the implement easier. Quick hitch adapter frames, according to the ASAE standard, are also made available to adapt the farm machinery to the tractor. Also provided on Allis-Chalmers tractors is a device for operating the lift of the three-point hitch from the rear of the tractor, thus avoiding the necessity for climbing on and off the tractor to adjust the height of the three-point hitch while hitching it to an implement.

In some of the state legislation concerning location of the SMV emblem, it was obvious the ASAE standards for the location of the SMV emblem were not followed. I am sure that if the people making these laws had thoroughly understood the requirements for different sizes of tires, different crop clearances, the requirement for articulation of the upper link of the three-point hitch, the space required for the hydraulic quick couplers and so forth, they would have made the law agree with the standards. They might also have considered the fact that a higher location of the SMV emblem will make it seen sooner as an approaching automobile is coming over the crest of the hill approaching the rear end of the tractor.

I had some slides that I was going to show, but obviously the talk has run more than the fifteen minutes allotted, so I am reserving those for later on this evening if people are interested in seeing them.

In summary, we think the voluntary standardization has been doing a fine job, as proven by statistical records. Howevr, we feel the farmer should be the one we listen to most in deciding requirements for regulation. We will, in any case, continue to do our part in making farm tractors safe.

CHAIRMAN HARTMAN: Thank you, Mr. Davis of Allis-Chalmers.

Next on the agenda, J I Case Company, Racine, Wisconsin, Mr. L. H. Hodges, Director of Research and Technical Services.

MR. HODGES: Good morning, Gentlemen and Mr. Chairman.

For the record, my name is Lawrence H. Hodges. I am Director of Research and Technical Services for the J I Case Company, Racine, Wisconsin. Our firm was founded in 1842 and we trust that our 128 years of experience qualifies us to make a few meaningful comments to the subject of agricultural tractor safety during this meeting. This subject is recognized by all as being far too broad and comprehensive for anyone to cover in the limited time available to us today. So our comments will focus attention or lend emphasis to four major points which be believe to be of utmost importance.

First, the voluntary industry standards. It is my understanding that the name and the general text of some 35 or 36 industry standards relating to tractor safety which have been adopted and published by either or both the American Society of Agricultural Engineers (ASAE), and the Society of Automotive Engineers (SAE), will be read into the record by some other groups before the Department of Transportation's study of tractor safety is completed, so I will not deal with this long list of standards, except to make three specific points.

One relates to the quality and the advanced state of the art of these standards. When the major companies in this industry began its major thrust in the development of roll-over protective systems in the early to mid 1960's, we learned rather quickly that the protective frame design criteria developed in other countries, such as Sweden, were totally inadequate for the larger and more powerful tractors for use on U. S. farms. On this point about the Swedish standards, we agree wholeheartedly with Professor Steinbruegge. However, our experience on testing against the recently adopted ASAE standard is in violent disagreement with his statement regarding the inadequacy of the U. S. standards.

So with the inadequacy found in the Swedish standards, we had to embark on a major research and development program to gain the new knowledge and the new technology for U. S. protective systems. The millions of dollars invested by the U. S. producers of tractors has resulted in the formulation of these present ASAE and SAE standards just recently adopted. They relate to the design and test standards and, in our experience, have proven to be the most stringent that exist anywhere in the world today.

Now, with those standards in mind, I would like to deal with a subject of what does it take in terms of investment, design, and testing, to provide protective equipment in compliance with these newly adopted standards. The significant investment by our company in the design and testing of a protective enclosure or a cab which conforms to the present standard I think is dramatically portrayed in a short movie which I would like to show. We believe that this film is representative of what other manufacturers have done, also, or are presently doing in their R&D programs to provide such hardware. As you look at this movie, keep in mind that it deals only with the protective enclosure which is one protective device, and the same expensive and design test program had to be undertaken or had to be duplicated just to provide the protective frame.

I realize that the movie isn't easily read into the written record, so I have provided a small piece of technical literature which covers this device.

(Document referred to retained for a time in the docket room of the National Highway Safety Bureau)

The movie will portray some of the testing that led to the development of this (indicating) tractor line portrayed by this scale model which is equipped with a protective enclosure system.

If we may have the movie, please.

(Movie shown.)

MR. HODGES: This film merely represents a small footage of what we clipped from the hundreds of feet that we have done in our testing work.

Now, through this short film, we trust that you have gained some insight to what it takes to supply protective enclosures that conform to the newly adopted industry standards. Please remember that this same program was also done for the so-called roll bar or protective frame.

The most gratifying thing about our new protective enclosure or our cab program is its user acceptance. Sales are accelerating at a rate which exceeds our highest expectations. This leads us to the conclusion that safety is a very salable package when combined with the other elements of comfort, convenience, noise controlling and other environmental control features. In fact, our one year's experience on protective control sales is already twice the previous history on these devices.

We strongly suggest that the present study being conducted by the Department of Transportation on this subject will in no way reflect or measure the impact on injury reductions which we can expect as a result of these new operator protective systems.

In the area of voluntary standards, the third point I want to make is the governmental presence in the development of these standards that we already have on the books. These present standards, which have been adopted and published by ASAE, enjoy a high degree of compliance by the industry and, in my judgment, are unique in that this professional society, ASAE, includes in its membership a large number of individual engineers employed by the government and by the Land Grant Institutions and Extension Services, and their contributions and participation in the final adoption of ASAE standards assures a much higher degree of governmental presence and public interest representation than can be found in many other areas of the voluntary standardization process.

Now, the second point I wanted to emphasize was the tractor and its infinite combination with implements and other equipment. In the development of any comprehensive tractor safety system and program, it must be kept in mind that a farm tractor is a tractor only at the instant it leaves the factory and during the time it moves through the distribution channels on its way to the customer. Once it is in the hands of the owner-user, it becomes a mobile power source to propel the operator in doing the useful work.

I think this infinite combination was adequately dealt with by our first speaker from the TOP Operator magazine, and I will skip forward on my script in the interest of time.

(Omitted remarks referred to follows:)

There exists an almost infinite number of different combinations of tractors and equipment. Some of it is built and attached to the tractor by the individual farmer. Some of these combinations may increase the hazards of tractor operation, whereas others may reduce some of the apparent hazards. Some farming operations cannot be performed and some equipment cannot be installed and used with operator protective frames or protective enclosures. Orchards, groves, and low clearance barns are good examples.

Tractor mounted cotton harvesters with overhead baskets cannot be assembled if the protective frame is in place, but the unit in itself provides a high degree of operator protection due to the nature of the design.

(End of submitted material.)

What is truly significant here, I believe, is the realization that it is impossible to accomplish a single design or system of operator protection by simple edict.

I would also like to emphasize the need for better accident statistics. We urgently need a tractor accident reporting system which provides the designer with information upon which to base future designs for safer tractors, and, in addition, one which provides a measure of the true effectiveness of new safety devices and features being introduced by the trade.

It is my understanding that the National Safety Council in our industry, in harmony with the Land Grant Institutions and Extension Services, are addressing themselves to this particular subject, and we are seconding the motion of other speakers in this area.

Certainly the fourth point that I want to make is the education of the operator, because his skill and competence are a key element in the man-machine-work environment interface and his education and training must be given top priority in any comprehensive tractor safety system.

It is our opinion, based on the analysis of current accident information and projecting on what we believe these improved accident statistics that we are appealing for here will show, that the young and the untrained operator are those primarily involved in the tractor accident safety. Education which reaches beyond the tractor design and beyond safety standards must be employed to the fullest extent to correct this situation.

Again, this subject has been dealt with by other speakers and I will move along.

(Omitted remarks referred to follows:)

We believe the agri-business community is more fortunate than any other in that years ago a farsighted government - the U. S. Government - established the Land Grant Institutions, the Extension Service, and the Vocational Agriculture program from which the 4-H and FFA activities have evolved. These provide the cornerstones for the launching pad of renewed efforts in education of the operator. We believe the total awareness of the tractor accident reduction opportunities are producing the desired synergistic effect.

(End of submitted material.)

In conclusion, let me emphasize these points. The total number of accidents in which the farm tractor is involved is not large in comparison to numerous other types and is decreasing.

Secondly, the voluntary standards program seems to be working well in our industry in recent years. It has accelerated dramatically with the net results of the most stringent and complete design and test standards for roll-over protective systems found anywhere in the world.

Next, protective frames and especially these protective enclosures are now being provided in ever increasing numbers in voluntary compliance with the industry standards and this should greatly accelerate the downward trend in tractor accidents.

The educational efforts in harmony with other phases must be employed to the fullest extent to remove the high incident operator from the tractor accident scene, and the computation and careful analysis of new and better tractor accident information which can measure the results of our diligent effort in the last several years should be seriously studied by all before embarking on new or ill-conceived programs which could lead to a serious imbalance between scientific relevance, social pertinence, and economic interest.

Thank you.

CHAIRMAN HARTMAN: Thank you, Mr. Hodges, of the J I Case Company.

I appreciate skipping over points made by previous speakers where your views are identical. They will go into the record and we can proceed on time.

Next on the agenda is the International Harvester Company, Farm Equipment Division, Mr. William J. McGary, assistant to the vice-president, and Mr. R. N. Coleman, engineer.

MR. McGARY: My name is William J. McGary and I am assistant to the vice-president of International Harvester Company, Farm Equipment Division.

We appreciate the opportunity to appear at this meeting and visit with you. We believe that our company's broad and long experience in the field of tractor design and our historic concern for and attention to the safety of the farm tractor operation can contribute to the objectives we all share with the reduction of farm tractor accidents to their feasible minimum.

At the outset, we would like to pledge the full cooperation of our resources in these discussions and those which may follow. These resources include the talents, expertise and experience of our safety and engineering people, as well as data we have at our disposal which would contribute to the body of knowledge which must be accumulated if we are to uncover the ways of even more effectively achieving farm tractor safety.

So we are in agreement with the intent of this study because there is always a need to obtain more information relating to the extent, cause, effect and prevention of farm tractor accidents. We accept our full share of responsibility as a leader in this industry. We agree, also, that there is a need for careful attention to all factors which contribute to farm tractor accidents whether they be human, environmental, educational, statistical and economic, as well as mechanical. We believe that a search for the true cause and effect of tractor accidents must not isolate any one of these factors from the others.

Just as a tractor design is not undertaken with performance or cost or capacity as a single benchmark against which we measure a tractor's marketability, the assurance of maximum protection for the farmer must be predicated on the exploration of all factors contributing to farm accidents.

It is, therefore, extremely important that ample opportunity be allowed all representatives of the agricultural and agri-business communities to contribute to the great body of knowledge which must be thoroughly developed and properly interpreted if your report to Congress is to bring about the fulfillment of your stated objectives.

Yours is a most difficult task within the time limitations imposed on you. We believe, however, that the time restrictions must not be allowed to interfere with an orderly and thorough study of all safety aspects pertinent to farm tractor safety.

We do not suggest delay. We do, however, suggest that while tractor safety can and will be improved, a "crash" approach or interim solutions would be unwarranted in light of the record. Studies and programs conducted in several states where reliable statistics are available bear out the fact that contrary to highway fatalities, farm tractor fatalities are diminishing.

So it is from a position of improvement that you undertake this study. In just a moment our staff engineer will review the development of those tractor safety features and devices which are in large part the result of our own design criteria. We are convinced that the safety features designed into our newer tractors have contributed significantly to this improvement.

They encompass safety features ranging from the more visible problems of PTO shielding and overturn protection to such lesser known considerations as location of operator controls, hitch and power line design.

They represent the design capabilities of engineers with backgrounds in many disciplines and in cooperation with such professional organizations as the Society of Automotive Engineers, American Society of Agricultural Engineers, American National Standards Institute, the International Standards Organization and others of equal competence, integrity and stature.

We are proud of these standards because they have been established and adopted through thorough and independent study by men who possess intimate knowledge of the tasks today's tractors are required to perform, as well as the environment within which they must perform their functions.

While they impose added engineering and manufacturing costs on both IH and the farmer customer, they have been adopted because we consider them essential to an operator's safety, compatible with the tractor's function, and consistent with the farmer's need for a fair return on his investment. These three factors, safety, function and cost, are basic to any consideration of farm tractor design. A safe tractor whose function and performance is materially impaired by unrealistic safety standards would be of little value to the farmer. The addition of unnecessary standards or standards of minimal value which would significantly increase the cost of the tractor would also add an unnecessary and undue economic burden on the farmer.

Over the years, our standards have been successful in melding these criteria into a safe, productive and profitable tool of the farmer's profession. This continues to be the direction of the thrust of our safety activities at International Harvester Company.

And now, gentlemen, I will introduce Mr. Richard N. Coleman, our staff assistant, test and development, who will review with you some of the major developments in farm tractor safety. By way of establishing Mr. Coleman's credentials, he was born and raised on a farm and graduated from the University of Nebraska with a B. S. in Agricultural Engineering. He has spent over 31 years in tractor engineering, is a registered professional engineer in the State of Illinois, and an active participant in tractor technical committees of both the Society of Automotive Engineers and the American Society of Agricultural Engineers.

Mr. Coleman.

MR. COLEMAN: Gentlemen, I want to review with you today just a few of the many International Harvester developments of the past 18 or 20 years that we believe have had a marked improvement on the productivity and safety of the tractor operator. Following this presentation, we will show two short film scripts, one entitled "International Harvester, PTO Shield Testing, 1970," and the other "Within The Frame of Safety." These also demonstrate our activity in the area of safety.

We have selected for this review our "Farmall Super M" model which was built in 1952, and our "Farmall 826" model which is being produced currently. These two models typically represent the design and safety of International Harvester tractors at the time they were produced. Also they represent the most popular power size of their time.

Now if we might go directly to the slides.

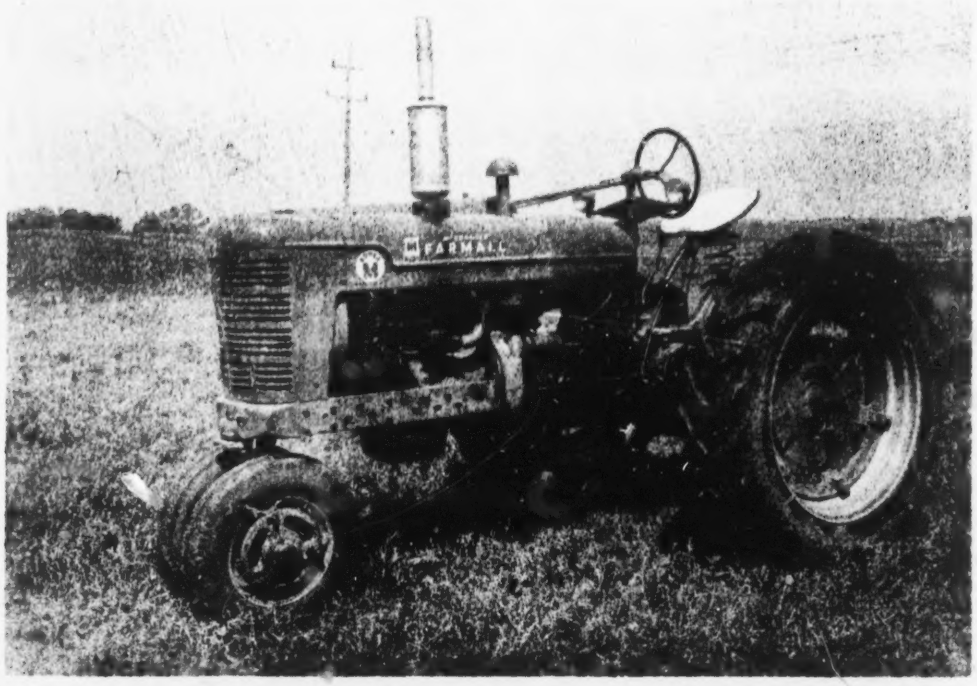

FIGURE 1 - 1952 "FARMALL SUPER M"

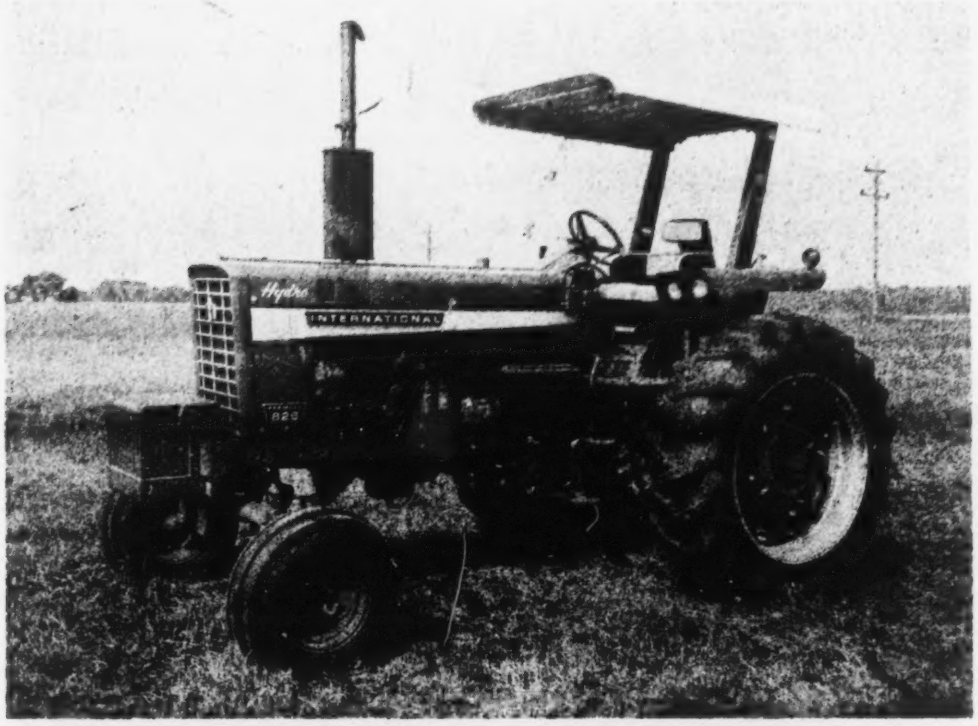
Hydro
INTERNATIONAL
826

FIGURE 1A - 1970 "FARMALL 826"

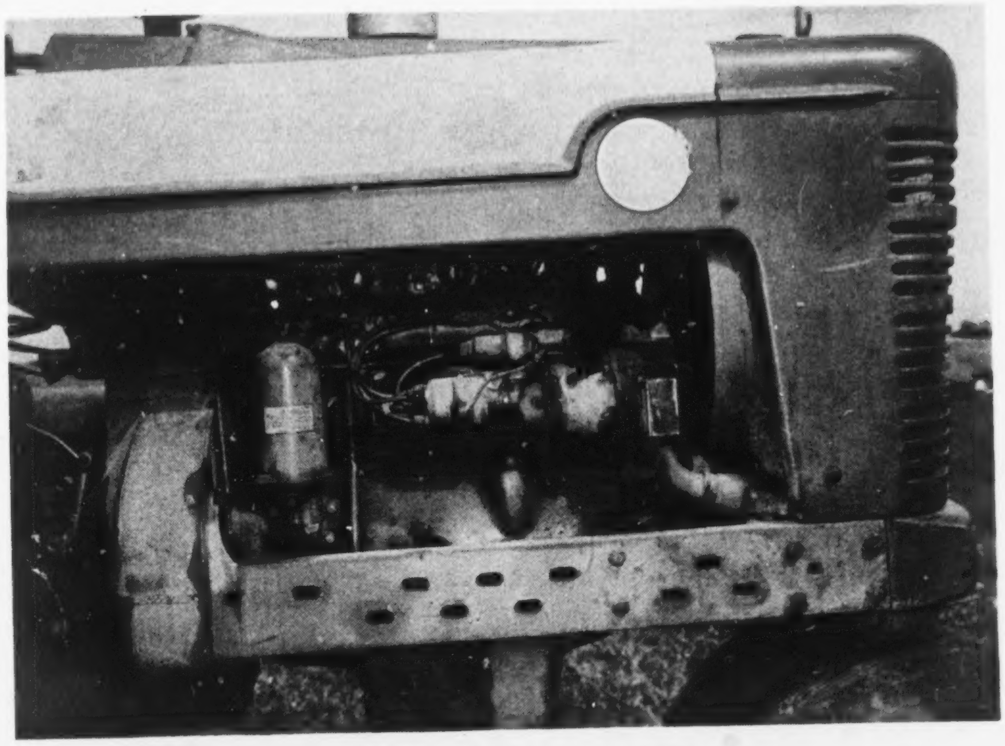

FIGURE 2 - 1952 "FARMALL SUPER M"

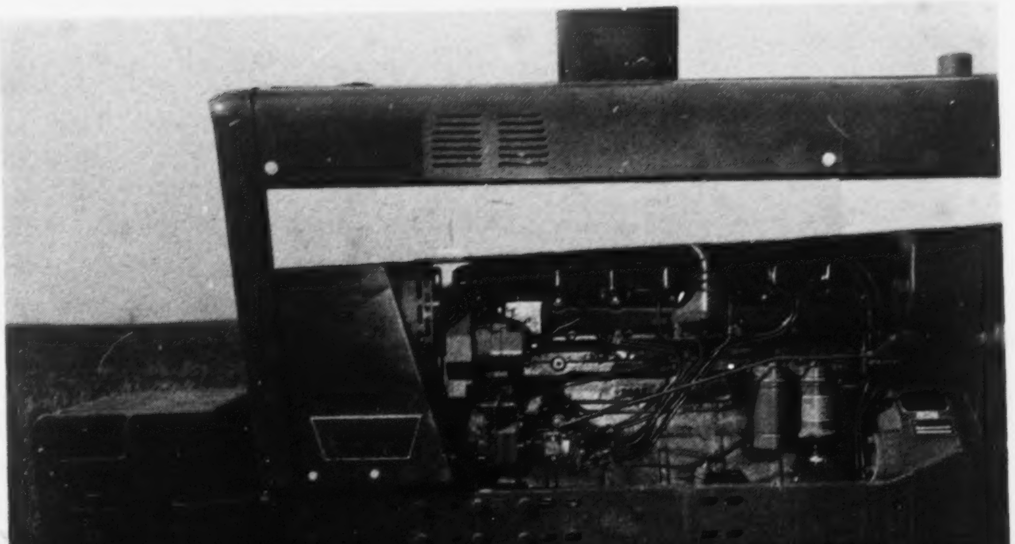

FIGURE 2A - 1970 "FARMALL 826"

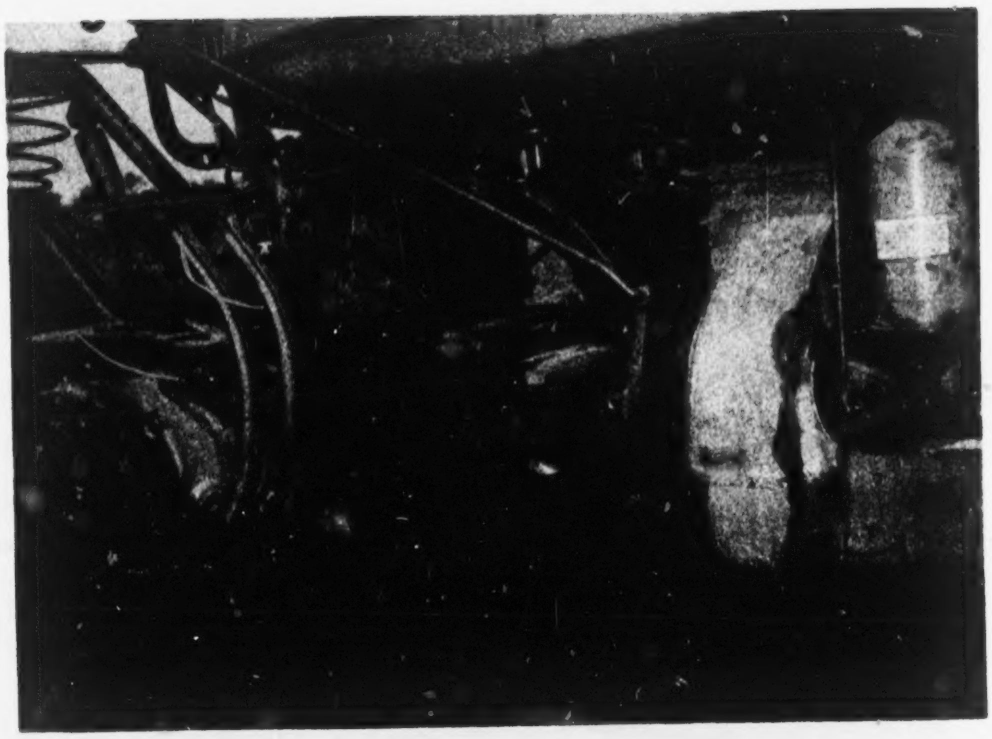

FIGURE 3 - 1952 "FARMALL SUPER M"

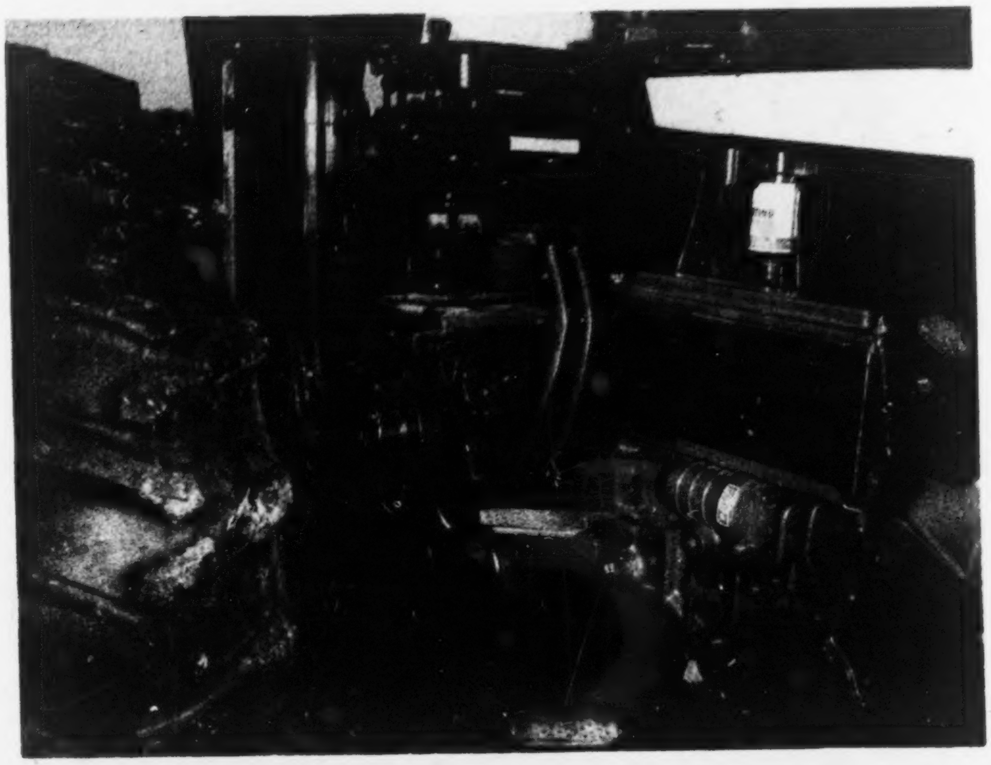

FIGURE 3A - 1970 "FARMALL 826"

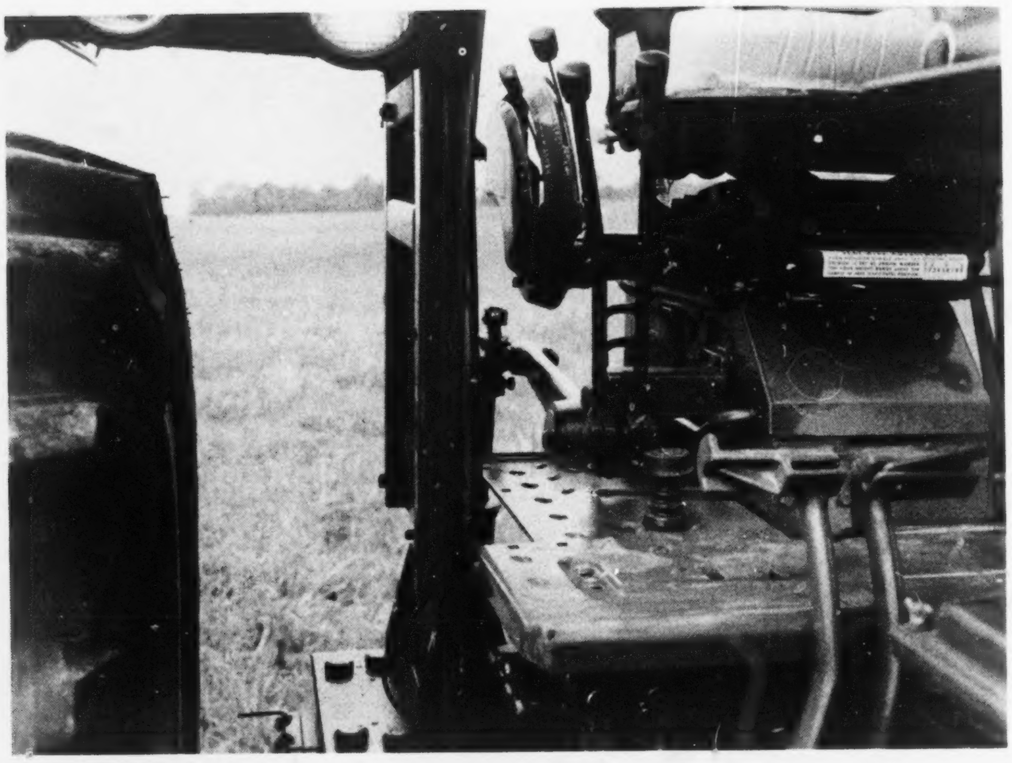

FIGURE 3B - 1970 "FARMALL 826"

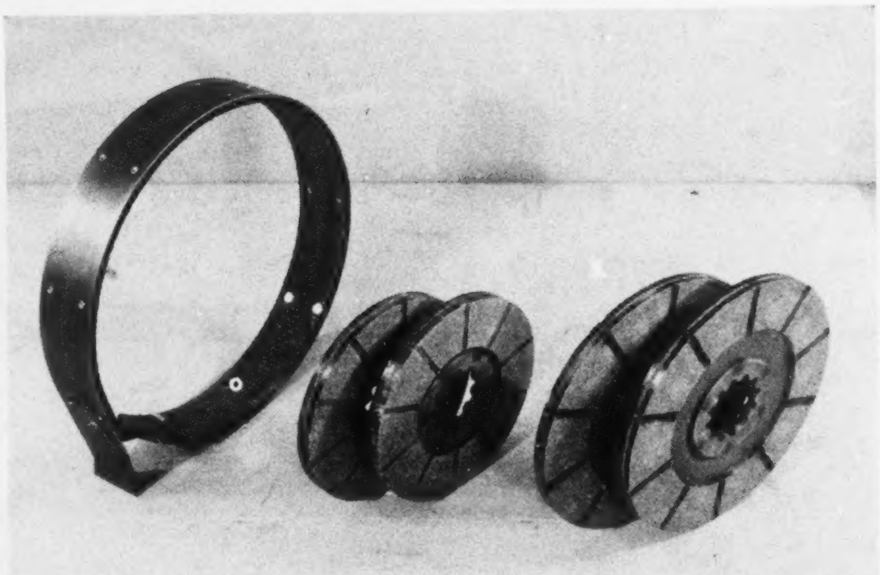

FIGURE 4 - 1946 "FARMALL M" BRAKE BAND
1942 "FARMALL SUPER M" BRAKE DISCS
1970 "FARMALL 826" BRAKE DISCS

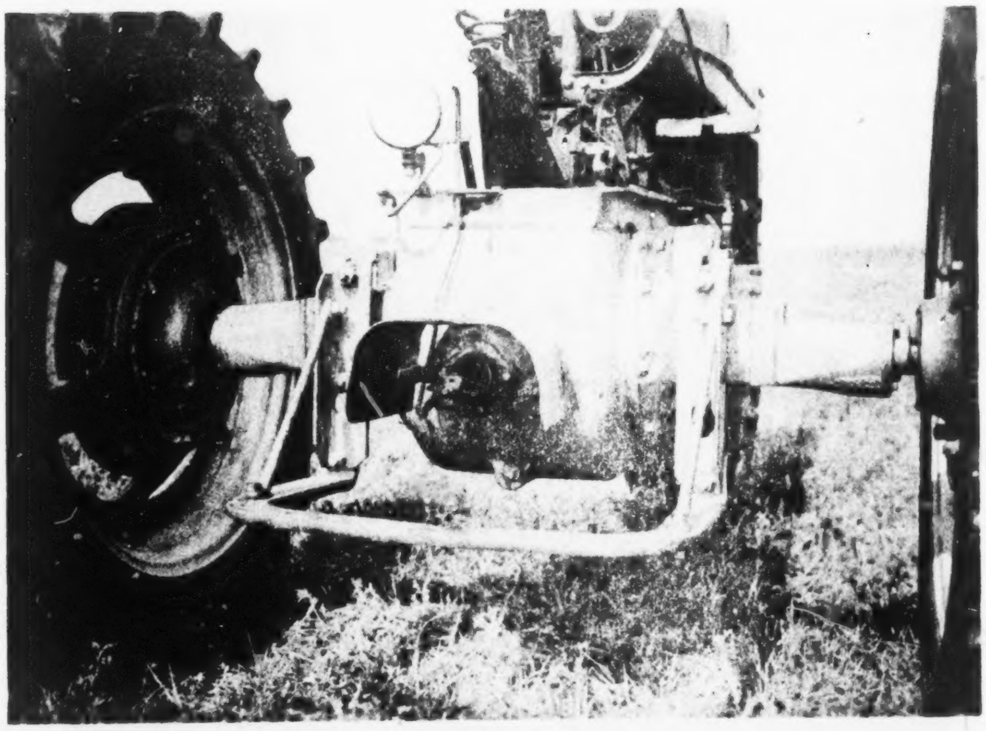

FIGURE 5 - 1952 "FARMALL SUPER M"

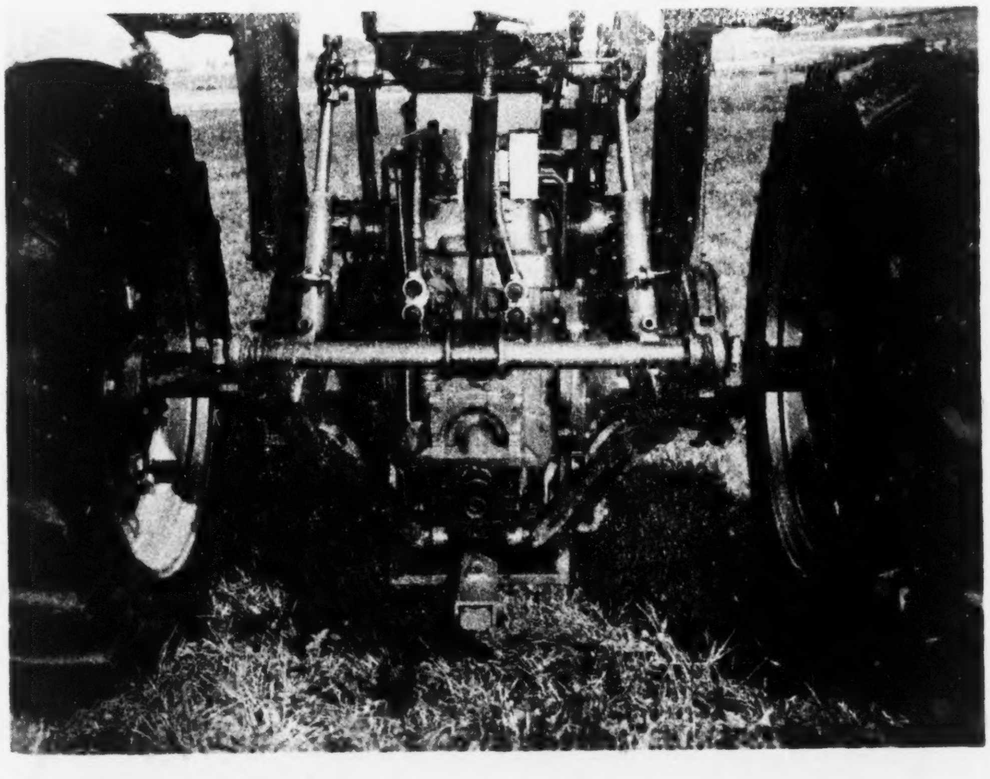

FIGURE 5A - 1970 "FARMALL 826"

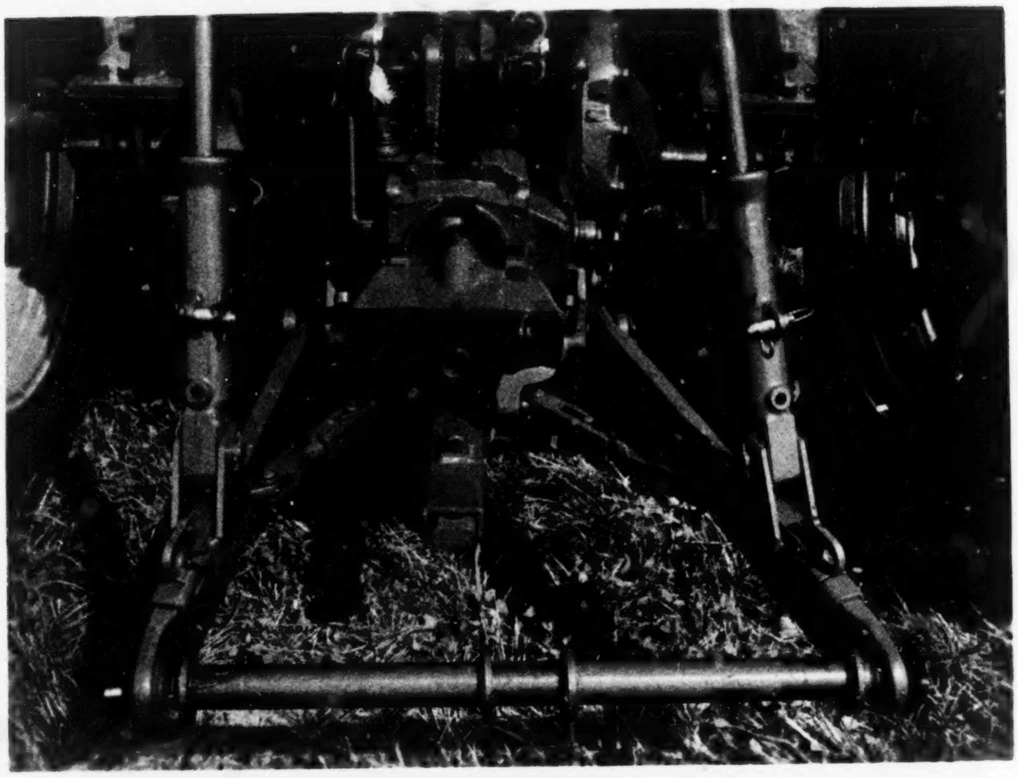

FIGURE 5B - 1970 "FARMALL 826"

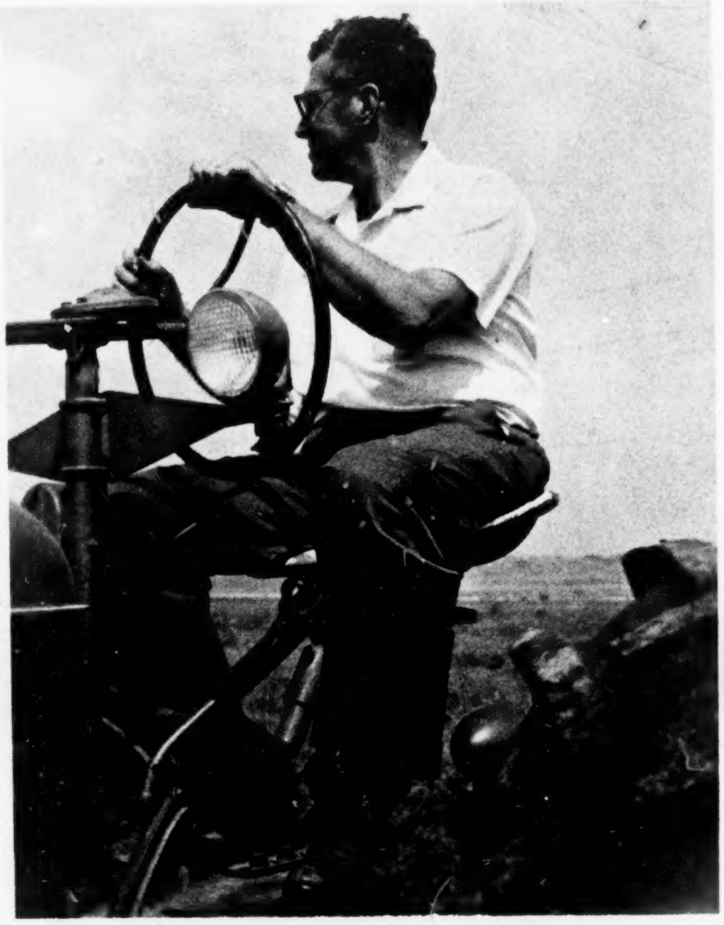

FIGURE 6 - 1952 "FARMALL SUPER M"

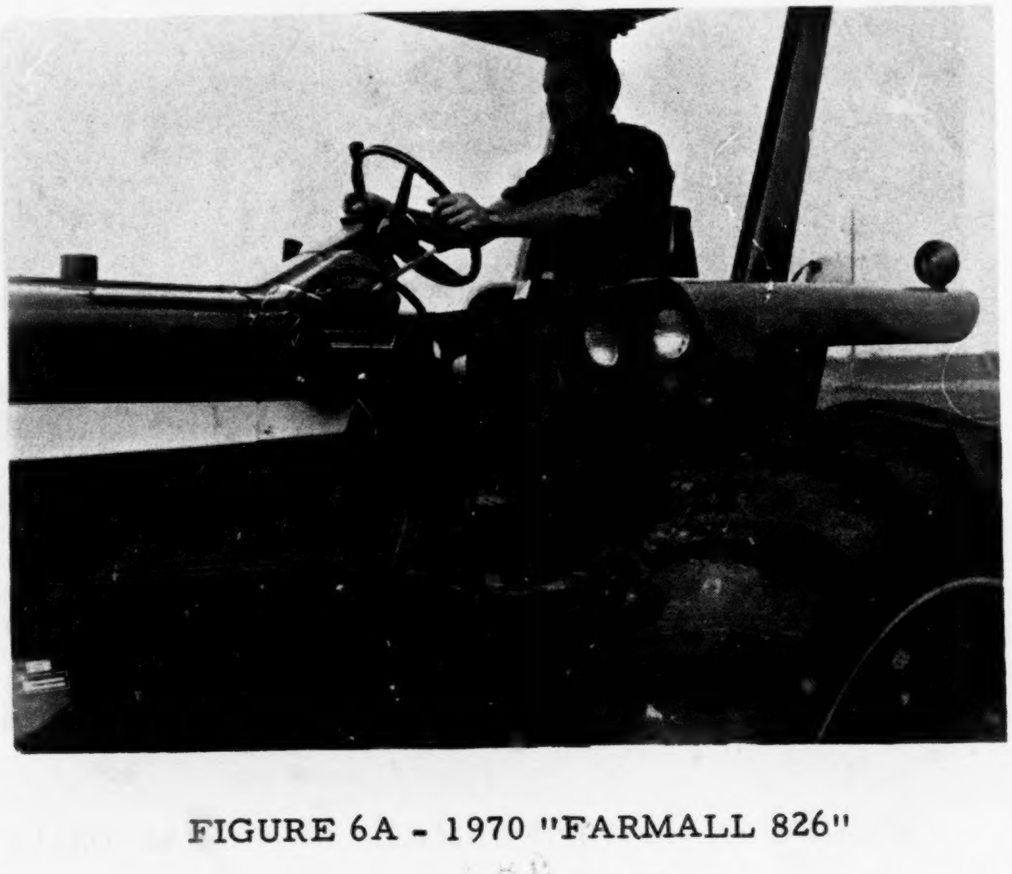

FIGURE 6A - 1970 "FARMALL 826"

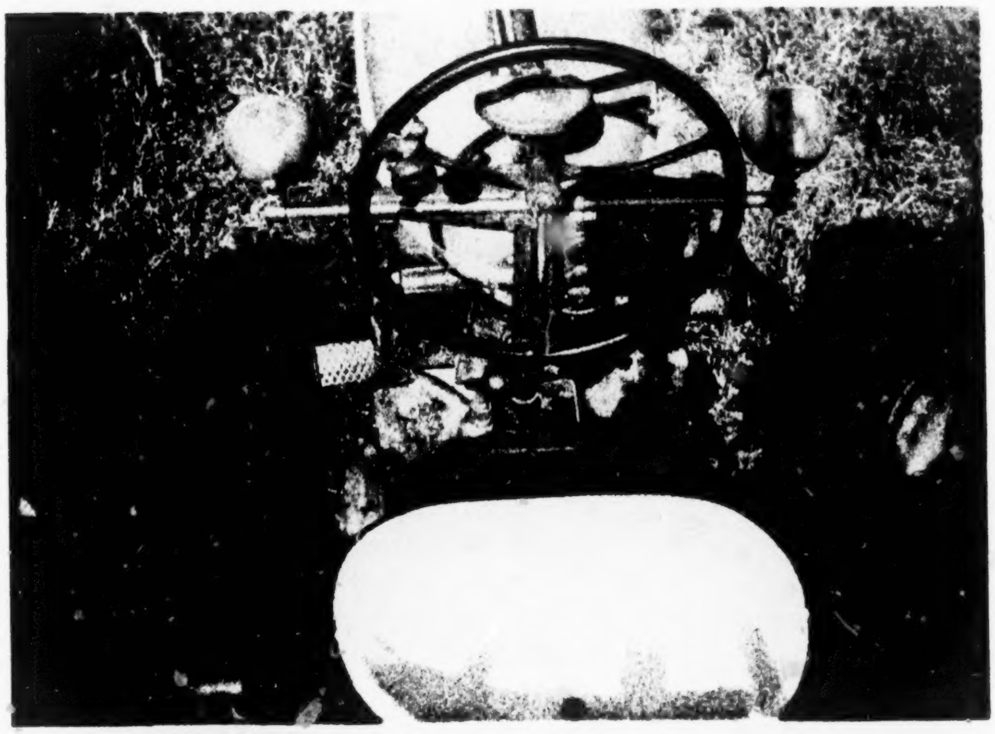

FIGURE 7 - 1952 "FARMALL SUPER M"

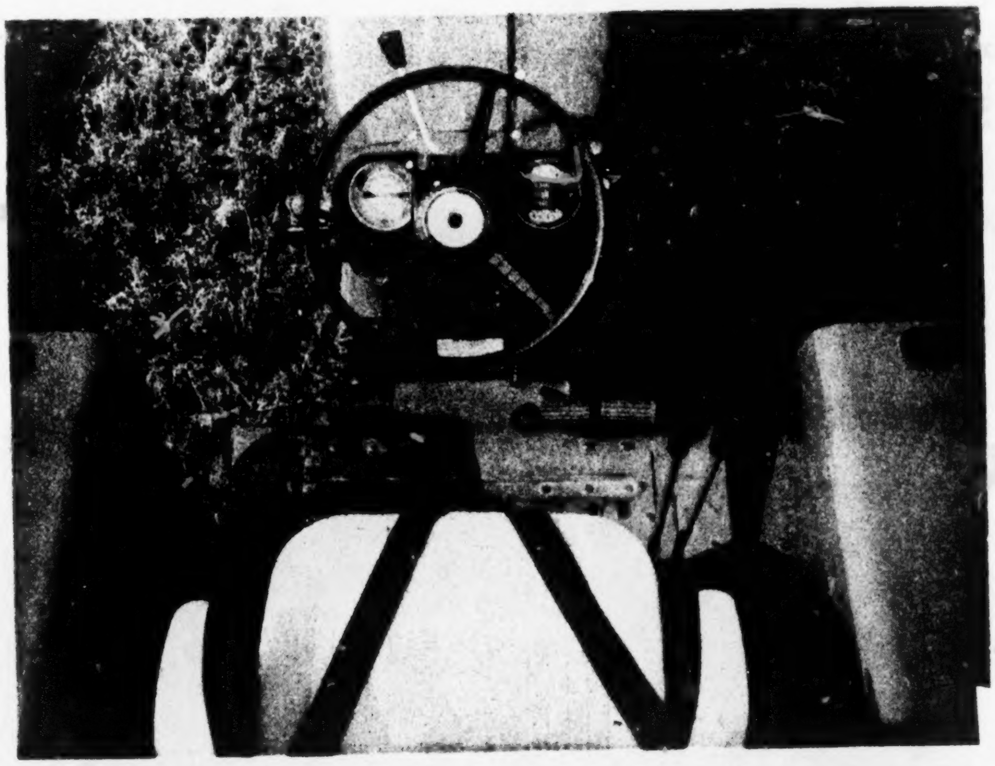

FIGURE 7A - 1970 "FARMALL 826" GEAR DRIVE

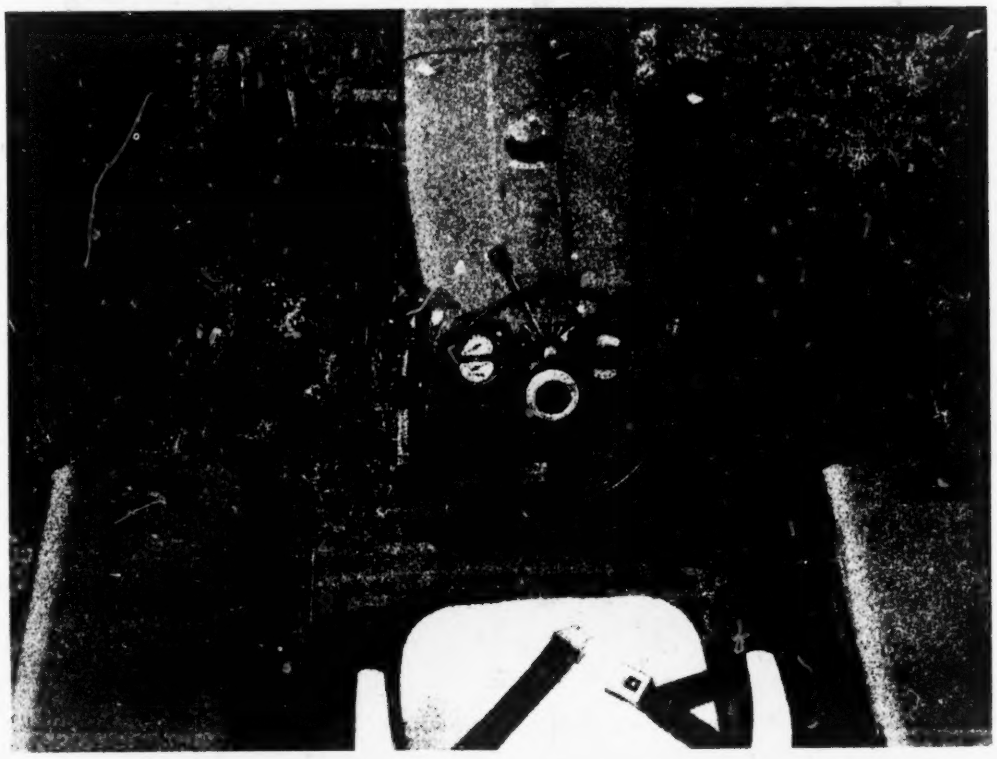

FIGURE 7B - "FARMALL 826" HYDROSTATIC DRIVE

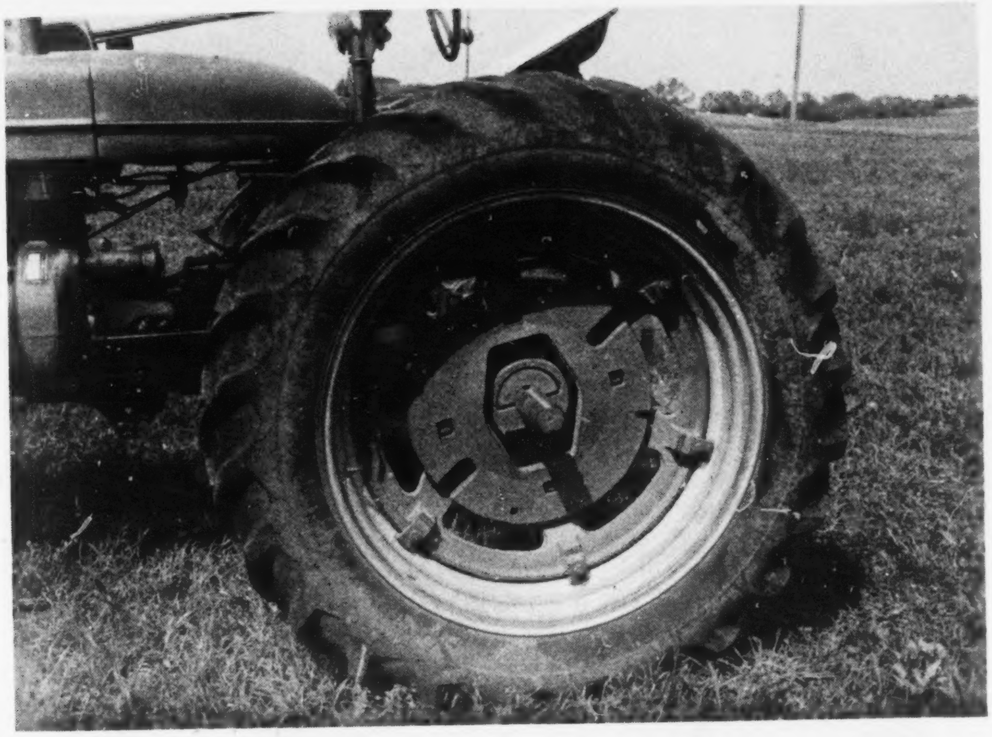

FIGURE 8 - 1952 "FARMALL SUPER M"

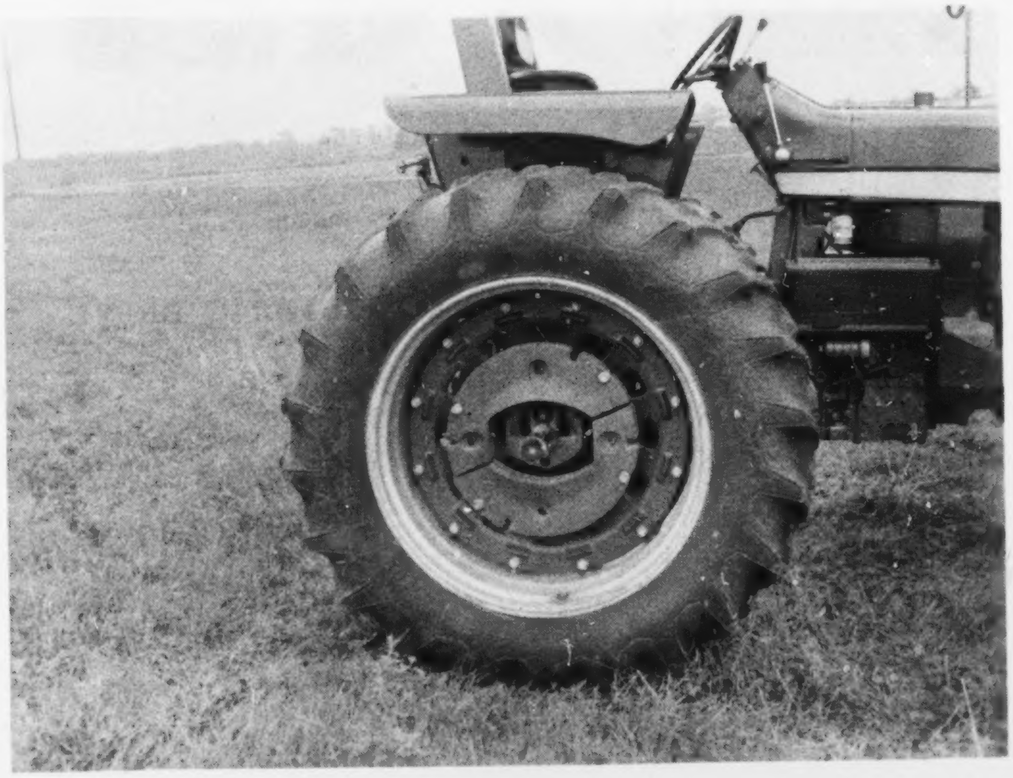

FIGURE 8A - 1970 "FARMALL 826"

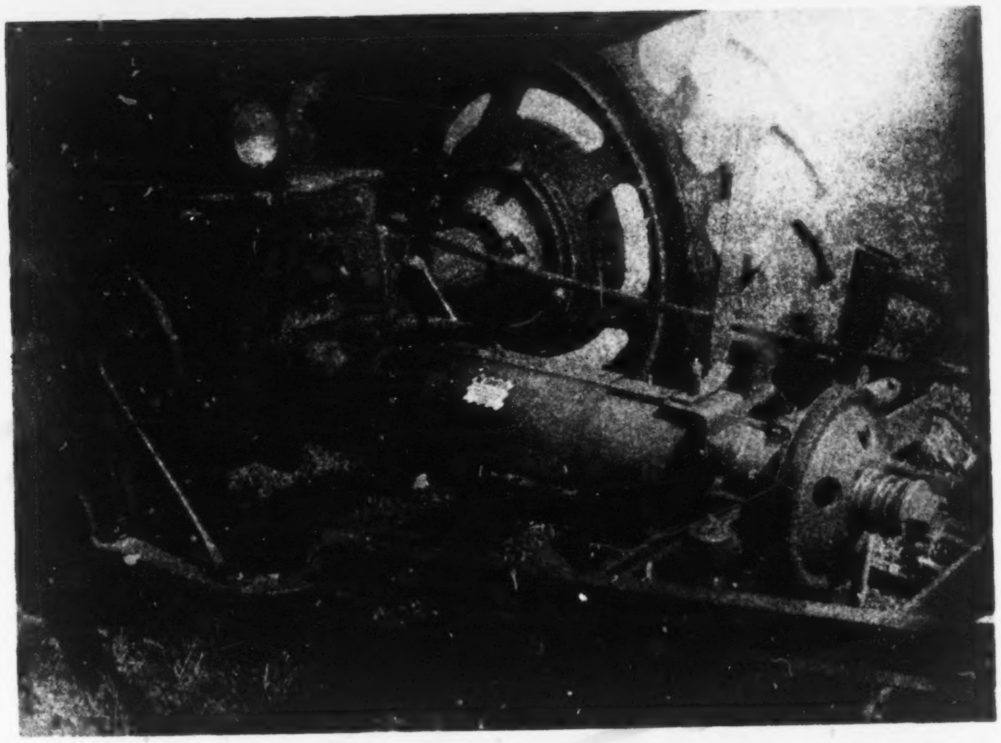

FIGURE 9 - 1950 "FARMALL SUPER M" AND SICKLE BAR MOWER

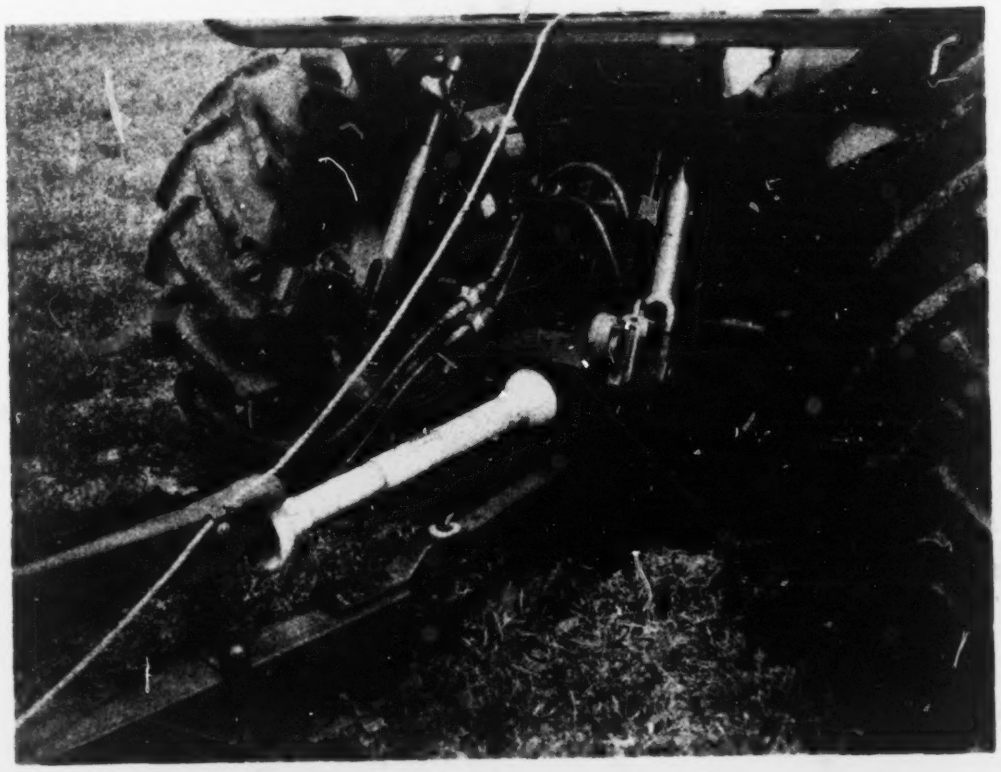

FIGURE 9A - 1970 "INTERNATIONAL 544" AND MOWER-CONDITIONER

Figure 1 is an over-all view of a "Super M" tractor that was produced in 1952, and has been in regular farm service by one of our customers for the past 18 years. We rented this tractor from our customer and the picture you see is as we received it. We did not clean this tractor or repair it in any way except for installation of a new seat pan. The padding on the seat pan had worn away completely. This tractor is in excellent operating condition as are many, many more of this model and other models this age. Tractors this age, and even older, fill an important role for the farmer today, not as his basic source of power, because these tractors do not have the features that have improved productivity as in later model tractors, but because they are excellent as standby or fill-in tractors, or as specialty tractors for short-time jobs.

I shall discuss in more detail certain features of this tractor so that you can better understand the progress we have made.

Please note the tractor is equipped with a tricycle-type front axle. This configuration was very popular in 1952, because it provided a very short turning radius which was important to avoid loss of valuable land for turning at the ends of the field.

Next, Figure 1A, is a picture of our current 92-horsepower "Farmall 826" tractor. Note that it is equipped with a wide adjustable front axle. This configuration has improved safety relative to a side overturn for two reasons: One, it cannot turn as short as the "Super M", nor does it need to. This is because as tractor power has increased, larger implements are being used, and the need for extremely short turning radius has been reduced; and two, the wide adjustable front axle with its center pivot provides restraint to tipping in a short turn. Under these conditions, the tractor can tip only a limited amount and then pivoting of the front axle is stopped, and the tipping axis moves out and is on a line which connects the outer edges of the front and rear tires. With the tricycle tractor, no such intermediate restraint exists; the tipping axis is on a line connecting the outer edge of the rear tire to the outer edge of the front tricycle wheel. We do not wish to mislead you, wide adjustable front axles were available for the older "Farmall Super M" model and a small percentage of this model were so equipped. Conversely, the tricycle front axle is available for the "Farmall 826" today, but only a very small percentage are so equipped. In fact, the standard tractor on the older "Farmall Super M" was equipped with a tricycle front axle, whereas the standard "Farmall 826" is equipped with a wide adjustable front axle.

I also call attention to the protective frame, mounting steps and seat. I will discuss them further later on.

As pictured by the slide, Figure 1A, the "Farmall 826" has a rear wheel tread setting of 80 inches from center of tire to center of tire. The total distance to the outside edges of the tires is 98.5 inches. This is a typical tread setting for both plowing and cultivating today. This center-to-center tread setting was also typical of the older "Farmall Super M" during the cultivating season. But in those days, a typical tread setting in the spring and fall plowing seasons was 72 inches center-to-center or 85.5 inches to the outside edges of the tire. Also, the minimum center-to-center tread setting available on the current "Farmall 826" is 60 inches, whereas on the older "Farmall Super M" the minimum tread setting was 52 inches. My point is this: Our tractors today have improved safety by virtue of their being used at wider tread settings.

Figure 2 shows this "Farmall Super M" was equipped with a four-cylinder gasoline engine. It ran at 1,450 rpm and produced 46 PTO horsepower. It was, however, also sold with a four-cylinder L. P. engine or a four-cylinder diesel engine. The gasoline engine was the high-volume seller. Figure 2A shows this current "Farmall 826" is equipped with a six-cylinder diesel. It is governed at 2,400 rpm and produces 92 PTO horsepower. This tractor is available with a six-cylinder gasoline or six-cylinder L. P. engine, but the diesel is the high-volume seller by a wide margin. The six-cylinder engine itself has been a big improvement with regard to operator fatigue. This is because the shaking forces in a six-cylinder engine are inherently in dynamic balance, whereas they are not in a four-cylinder engine. The vibration on steering wheel, platform, seat, et cetera, is much less than it was on the "Farmall Super M".

One further word before we leave this subject of vibration. We still use four-cylinder engines in farm tractors below 60 PTO horsepower, but now we use aluminum pistons which are lighter and result in less shaking forces. Also, any four-cylinder engine we now use above 40 PTO horsepower is equipped with a separate dynamic balancer. The simplest description of a dynamic balancer is that it is a set of precision weights driven from a gear on the crankshaft. The weights are of such size, rotating speed and proper phasing that the inherent unbalance of the four-cylinder engine is eliminated.

I direct your attention to brakes. Figure 3 shows the brake housing of the double disc mechanical brake on the "Farmall Super M" is located on the bull pinion shaft which is, in turn, directly connected to the rear axle through the bull gear. Note that there are individual brake pedals for the right and left brakes. This is an important performance and safety feature on two-wheel drive farm tractors, because under certain conditions of field operation such as heavy pull on loose soils, the front wheels cannot get enough bite to provide steering control of the tractor. The individual wheel brakes are then used. They are very effective in this type steering operation. The brake pedals are locked together to provide simultaneous safe braking for transport operation.

Figure 3A shows the current "Farmall 826" brake housing. This tractor also has double disc brakes located on the bull pinion shafts. These brakes, however, are hydraulic power actuated, self-equalizing, and self-adjusting. Hydraulic power for actuation is obtained from a pump located in the housing just back of the engine. This pump is driven from a separate shaft that is directly connected to the engine and is "live hydraulic power." It is no way affected by the engine clutch or transmission operation.

There are three important advantages over the brakes of the "Farmall Super M." One, there is a reduction in pedal effort to obtain the desired braking action, yet there is feel, i. e., the total braking ability is in proportion to the pedal effort. Two, equalization of left and right brakes is not dependent upon equal adjustment of both brakes. If both brakes are applied, the hydraulic pressure to both brakes is equal. And, three, the self-adjustment feature results in no brake adjustments until such time as replacement of the lining is required.

I would like to go back even further than twenty years. Disc brakes, which most of you probably realize are a premium item on automobiles, have been a standard feature on our high-volume farm tractor models for over twenty years. Such was not always the case. Our famous "Farmall M," the model we produced just prior to the "Farmall Super M," was equipped with band brakes during most of its production life. In Figure 4, here, we see the brake friction members for a single wheel, the band for a "Farmall M," the double discs for a "Farmall Super M," and the double discs for a "Farmall 826." The discs are a marked improvement over the band for two main reasons. One, they are much less subject to brake fade because they have flat surfaces which results in uniform pressure distribution of the brake application forces. And, two, the linkages between the application of the operator's foot and the application of pressure to the friction surfaces are much less subject to permanent deformation which, in turn, requires additional brake adjustments to obtain equal braking ability between left and right brakes. This, along with the developments I've already described, have definitely improved safety in tractor operation.

On the "Farmall Super M" the hydraulic power lift pump was located in the area just in front of the transmission and is driven from a transmission shaft. The proper descriptive terminology is "transmission-driven hydraulic power lift." This produced hydraulic power for lifting and controlling implements whenever the engine was running and the engine clutch was engaged. If the clutch was disengaged, the hydraulic power lift pump was not running and no hydraulic power was available.

On the current "Farmall 826," the hydraulic power lift pump is located in the area just behind the transmission. This pump, however, is driven from a separate shaft that is connected directly to the engine.

Hydraulic power is in no way affected by the position of the main engine clutch. In other words, hydraulic power is available to do work whenever the engine is running and is in no way affected by what the transmission is doing. The proper descriptive terminology is "live hydraulic power," as opposed to "transmission-driven hydraulic power" for the "Super M." The controls for this live hydraulic system are conveniently located for use by the operator.

I would like to paint a mental picture of how the "live hydraulics" on the current "Farmall 826" has increased the productivity and improved safety for the operator. Picture yourself doing a job of mowing hay. You are mowing along a fence row trying to get all the hay right up to the fence when you suddenly realize the outer end of the sickle bar is about to hit a fence post. You must stop the tractor, lift the sickle bar with hydraulic power sufficiently to clear the post, and then proceed. With the "Super M," the following actions would be required. Disengage the clutch, apply the brakes, put the gear shift lever in neutral, re-engage the clutch, lift the sickle bar with the hydraulic lift lever, disengage the clutch, put the shift lever back in gear, engage the clutch, move forward, and then drop the sickle bar back to working position after proceeding beyond the post. With the current "Farmall 826" and its live hydraulics, two movements of the clutch pedal and two movements of the gear shift lever are eliminated from this procedure. Hypothetically, I could go on painting mental pictures, but would suffice it to say, however, that "live hydraulics" have improved safety by reducing the thought and action requirements of an operator in emergency situations.

Over the years, much attention has been directed to safety during tractor power take-off operations. These are pictures, Figures 5 and 5A, showing the PTO for the "Farmall Super M" and for the "Farmall 826." At the output end they look somewhat similar except on the "Farmall 826" two shafts are shown. One runs at 540 rpm, the other at 1,000 rpm. These speeds are both currently standard for interchangeability and power requirement reasons. There is, however, a really significant difference between the PTO units. The "Farmall Super M" PTO is driven from a transmission shaft and it does not run when the engine clutch is disengaged; the correct descriptive terminology is "transmission-driven PTO." The "Farmall 826" PTO is driven from the separate shaft, directly connected to the engine. Its operation is in no way affected by the position of the engine clutch or the operation of the transmission. There is a separate clutch in the drive line so that the PTO can be disengaged or engaged independently of any other tractor action.

Consider a forage harvesting operation where the forage crop is not uniform throughout the field. As the operator moves through the field, he encounters an area where the crop is considerably thicker and he notes that his forage harvesting machine is about to be plugged. The older "Farmall Super M," with its transmission-driven PTO, is at a definite disadvantage under these conditions. If the operator releases the engine clutch to stop forward motion, the rotating members of the harvesting machine also stop and the machine will quite likely be plugged, thus subjecting the operator to a hazard during the unplugging operation. The "Farmall 826," with its independent PTO," handles this situation easily. The operator can disengage the engine clutch, stopping tractor forward motion, but the forage harvester continues rotation, thus clearing itself of the possible plugging condition. The operator can also shift to a lower gear and proceed at a slower ground speed, thus resulting in a crop flow into the machine at a rate that can be successfully handled. To do this with the older "Super M," the rotating members of the harvesting machine must come to a complete stop.

The "Farmall 826" and its independent PTO provides another important safety advantage. When making short turns with PTO-driven machines, the PTO drive can be disengaged and re-engaged without stopping forward motion of the tractor. My whole point is that the "independent PTO" increases the operator's productivity and improves safety to a marked degree.

Figures 5 and 5A also show the older "Farmall Super M" is equipped with a conventional drawbar, while the "Farmall 826" is equipped with a conventional drawbar and a hydraulically-controlled three-point hitch for mounted and semimounted implements. This is typical of the way these row crop tractors were and are sold and used. In fact, a hitch with hydraulic controls was not available from the factory for the "Farmall Super M." This "Farmall 826" hydraulically-controlled hitch with draft sensing has some important advantages. One, with mounted and semimounted implements, gage wheels that are necessary on trailing implements can be removed. The vertical forces usually carried by these gage wheels are applied to the tractor, thus reducing the possibility of the wheels spinning and getting stuck. In addition to this, the draft sensing of the hitch automatically reduces the cutting depth of an implement when a tough spot is encountered, which also reduces the possibility of getting stuck. Hazards exist when a machine is stuck. Two, the additional forces that are applied to the tractor as a result of eliminating the gage wheels also means the ballasted weight of the tracgor can be less for a given condition. This, in turn, means improved safety relative to rear tipping when the tractor is being operated without the implement. And, three, mounted and semimounted implements are more maneuverable than trailing implements. For instance, they can be backed into fence corners and can be gotten out of tight spots more easily.

Figure 5B is similar to Figure 5A except the hitch has been lowered, and it is shown swung to one side of center. It is important for some mounted implements that the hitch be able to swing back and forth, thus permitting the implement to traverse a desired course.

The hitch is designed so that when it is lifted, as shown in Figure 5A, the hitch is centered and swing is restrained. Free swinging during transport operations which might cause tractor control problems is eliminated.

My point relative to hitching is this. The "Farmall 826" is designed and developed along with the implement to increase the productivity of the operator and to avoid getting into troublesome situations.

These pictures (indicating), show the operator's station from a point approximately at the operator's eye. Figures 6 and 6A show seated operators on both tractors. On the older "Farmall Super M," the seat is of the pan-type without back or armrests as compared to upholstered armrests and seat back on the "Farmall 826." The addition of the seat back and armrests is a decided improvement in avoiding an operator fall-off while operating on very rough terrain. Also note that on the "Farmall 826" with the protective frame, a seat belt is used.

The gear shift lever on the "Farmall Super M" was located between the operator's legs and was, in fact, somewhat of a nuisance in this position, particularly when mounting, dismounting, and when the operator shifted seating positions to avoid fatigue. On the "Farmall 826" all the gear shift and speed ratio controls have been moved up to the side of the steering wheel, thus providing much better leg room for the operator.

Figures 7 and 7A show the operator station from a point approximating the operator's eye. There are several items here I would like to discuss.

One, on the "Farmall Super M" the operator deck or footrest was directly on the tractor rear frame cover and was quite narrow as compared to the platform on the "Farmall 826." This "826" platform has further isolated the operator from vibration, heat, et cetera, as compared to the "Farmall Super M."

Two, all the instruments on the "826" are located on a special instrument panel in easy view of the operator. Also, this instrument panel and the gear shift pattern have special night lighting. These are improved safety items as compared to the "Farmall Super M."

Three, the "Farmall Super M" had a push-pull switch. The "Farmall 826" has a removable key switch. This is an improved safety item to prevent unauthorized operators from using the tractor.

Four, the park lock provided on the "Farmall Super M" has a ratchet and pawl which the operator used to set the brakes when he left the tractor. This pawl, however, was in a pretty awkward position to actuate by hand. On the "Farmall 826," with its hydraulically-actuated power brakes, the park lock is a special transmission lock within easier reach of the operator.

Five, the "Farmall Super M" had a five-speed transmission with one reverse, thus resulting in six positions for the gear shift lever. The "Farmall 826" has a four-speed transmission with a high-low gear box behind it and an optional high-low power shift range box, "torque amplifier" in front of it, thus more ratios to better match job conditions. The transmission and the high-low reverse gear box controls are located to the right of the steering wheel. The top governed transport ground speed is about the same for both tractors. I should state that a very large percentage of all the gear drive tractors are ordered with the power shift torque amplifier. The torque amplifier itself is an improved safety item because it permits the operator to change one ratio or ground speed "on the go" without declutching to meet varying field conditions. Any time a field-plugging condition or work-stopping condition can be avoided, safety is improved.

On the "Farmall 826," the hand-holds in the fenders and around the transmission controls are shown. These are to aid the operator in mounting and dismounting from the tractor. These, along with the mounting steps shown in Figures 1A and 3A, have improved the operator safety during mounting and dismounting. Normally the operator mounted the "Farmall Super M" tractor by stepping on the drawbar and onto the rear frame cover, throwing his leg up over the seat to place himself at the operator station. Referring to Figure 5 again, a clearer view of how the drawbar acts as a step can be seen. We have shown this "Farmall Super M" without fenders because this is the way we obtained it from the owner. I understand he had fenders for it, but had removed them. When the fenders were in place, mounting the tractor from the front was impractical. These with the steps that I pointed out in the first slides are a definite improvement.

This (indicating), Figure 7B, shows the "Farmall 826 Hydrostatic Drive" tractor as opposed to the gear drive tractor shown in Figure 7A. Operator controls and instrument location is very similar. I do, however, want to discuss a number of safety improvements that are provided by this hydrostatic drive.

One, this hydrostatic drive tractor provides an infinite number of speed ratios, thus the operator can adjust the transmission speed ratio "on the go" to meet any field condition.

Two, there is still a control pedal in the same location as the regular clutch pedal. This control pedal acts very much like the regular clutch pedal, i. e., whenever it is depressed, the drive from engine to rear wheels is disconnected, but the tractor is not in a free coast as would be the case with a regular clutch pedal. Under these conditions, whenever the ground speed of the hydrostatic tractor exceeds a speed previously selected by the speed ratio lever, automatic engine braking takes place, thus it is not possible for an operator to freely coast down a steep hill at excessive speed by simply actuating the pedal.

Three, the controls of the hydrostatic transmission are so designed and developed that the operator can quickly move the speed ratio lever from one position to another without encountering undue jerks due to high deceleration or acceleration.

Four, the speed ratio quadrant has a Z-type pattern. Any position forward of the horizontal portion of the "Z", controls forward motion. Any position rearward controls rearward motion.

Five, this hydrostatic transmission was very carefully designed and developed with safety in mind, and we believe it is a definite advancement in the state of the art, even when considering inexperienced operators or operators who may have physical shortcomings.

In Figures 7, 7A and 7B our attention is directed to the steering wheel, so an explanation of how developments in steering have improved safety is in order. The "Farmall Super M" was equipped with a worm and gear mechanical steering system. The worm and gear had been carefully developed to give easy mechanical steering with as little kickback or reversibility as practical. It was a good steering system for its day, but if one of the front wheels encountered a severe obstacle, there was a feedback to the operator's hands. In fact, if he were not paying attention, the steering wheel might even be spun out of his grasp. The "Farmall 826" is equipped with hydrostatic power steering as standard equipment. It has been designed and developed so that it takes very little effort to steer, and yet the steering wheel will not be spun out of the grasp of the operator even when encountering very severe obstacles with the front wheels.

One other word about hydraulic power steering and brakes. The hydraulic pump supplying power for these items is gear-driven, and thus reliability is greatly increased over that if it were belt-driven. Even so, if hydraulic power is lost, both steering and braking is still possible through hydraulic power generated by hand on the steering wheel and by foot on the brakes.

As a farmer uses his tractor throughout the seasons, it is oftentimes desirable, indeed it may be necessary, to change the weight balance of the vehicle. On the "Farmall Super M" a relatively small amount of ballast could be placed on the front wheels by adding front wheel weights . On the "Farmall 826" the job of changing the front ballast has been made easier by supplying easily removed front weights in either 65- or 100-pound pieces.

Figures 8 and 8A show how the rear wheel weights have been changed to make the job of changing the ballast on the rear wheels easier. The "Farmall Super M" had a one-piece rear wheel weight weighing about 150 pounds. The "Farmall 826" has a two-piece rear wheel weight, each weighing about 75 pounds.

We have briefly discussed a number of items relative to operator safety and productivity as affected by tractor developments. Many more items could be presented, but in real life, the tractor is only a source of power. It must be used with an implement or some other tool in order to bring a return on the farmer's investment, so safety should always be viewed in light of the entire system, i. e., the tractor and implements.

These are our final slide pictures. Figures 9 and 9A show an example. Figure 9 shows the "Farmall Super M" attached to a sickle bar mower drive typical of its time. Note the telescoping-type or tunnel PTO shaft shield. Figure 9A shows our current "International 544" utility model tractor attached to a current sickle bar mower-conditioner. The PTO shaft is shielded by a current journaled integral shield. This integral shield never needs to be removed from the shaft and, in fact, is very difficult to remove. Safety has been improved in two ways. One, the shield is more effective because it does not have an open area on the bottom, and two, hooking up without the shield is impractical.

This slide pictures the PTO shielding we provided in 1952, as compared to our current integral PTO shield.

We are presenting to the Department of Transportation a document covering these items and many more. For example, steering-hitching. We could present much more information with regard to tractors, tractors and tillage tools, tractors and harvesting tools, tractors and material handling tools. Each discussion could easily be as long as the one we have already presented. International Harvester has been working on safety of the tractor and implements with as much vigor as we have on the tractor itself. We fully expect our improvements in the future will be even more dramatic than those of the past.

We will now show the film, please.

(Film shown.)

MR. COLEMAN: This film was taken from films we produced from our own PTO shielding. As shown in our slides, the drive line, with a free rotating co-axial shield, along with the fixed shield on the tractor and fixed shield on the implement is currently being used. We are here showing an experimental PTO drive line with a flexible shield completely covering the forward universal joint. The rear joint has been left as is to show the difference.

This is a test picture we used to simulate accidental contacts that may occur with a person and a PTO shaft. The forces there as simulated shows a 180-pound man, the simulated pant leg contact from the rubber shield, shield contact from the shield. Now, down on top, notice how quickly the PTO shield stopped turning, it is right on the rubber shield portion. The PTO shaft itself continues to run.

Here we are using a dummy and it can be dropped directly down on the PTO shaft. It stopped turning, the shield did. Now we have disconnected the PTO shaft. The dummy is slowly being lowered over the PTO shield with one leg rubbing. Notice it stopped turning? It might be turning just slightly. The PTO shaft itself is running.

Here a glove is being forced into the convoluting rubber shield. Notice it does not wrap it up.

And our final scene where we will take the neck tie of the dummy, tape the neck tie of the dummy directly to the PTO shield and the PTO will be started. Notice how quickly the shield stops, but the PTO shaft itself is still running.

Now there will be just a short break here and we will go directly into the other film strip.

(Movie shown.)

MR. McGARY: On that power take-off film, you might ask yourself why we don't have that device today in production. Well, for this reason. This shield has passed all laboratory tests. You see we were using, of course, a dummy on it. The validated design functions and durability calls for extensive field testing under actual working conditions. This is our policy and practice and we intend to do this in regard to the development of this power take-off Dick was telling you about. This is our policy where safety is concerned, like anything else, naturally. The film you saw on the protective frame has been seen by millions of people throughout the United States and overseas and also on television programs.

This concludes our part of the presentation. We appreciate your time and attention. We hope that you can now share our faith and our pride in the workability of the International Harvester approach to product safety.

We pledge continued attention to the protection of our farm customers. We consider it a moral as well as a business responsibility.

Thank you very much.

CHAIRMAN HARTMAN: Thank you.

The last one on the agenda this morning, O. Edward Kurt and Associates, Mr. John Gellatly.

Would you give your name and occupation.

MR. GELLATLY: Mr. Chairman, Ladies and Gentlemen.

My name is John Gellatly. I represent O. Edward Kurt and Associates of Royal Oak, Michigan. My occupation is that of tire consultant. After 34 years employment by six tire companies in the design, testing, and manufacture of tires, I recently associated with a firm of scientific consultants in the Detroit area, doing business under the name of O. Edward Kurt and Associates. It is as a member of that organization that I present the following comments to this meeting concerning the hazards involved in the mounting and inflation of large agricultural tractor tires.

During 1968 and 1969, six new unused agricultural tractor tires were submitted to us for scientific examination and evaluation because persons had been injured while mounting and inflating these tires. One bead of each tire was reported to have been blown over its rim flange during the inflation process so that either the bead and sidewall of the tire struck the operator, or, with the tire resting on the floor in a horizontal position, the bead pressed against the floor and the tire and rim were propelled upward. All of the wires were found to be broken in one location, as determined by flexing the bead by hand and then having it X-rayed.

Dr. Kurt has accumulated vast experience investigating and testing passenger tire bead failures in over 50 such accidents during the past 18 years. Each of the six agricultural tire accidents has been investigated to evaluate the following three possible causal factors:

One, the bead wires were broken in the tire factory, and thus are in a broken condition when the tire is mounted on the rim, permitting rubber and fabric to stretch over the rim flange.

Two, the wires are broken during the mounting procedure by not accurately centering the bead on the rim, and thus subjecting the bead wires to abnormally high stress while inflating the tire to seat the beads on the rim.

Three, the bead is properly centered on the rim, but excessive pressure is required to force the beads properly out against the rim flanges.

The Rubber Manufacturers Association, with offices in New York City, has issued a brochure concerning agricultural tires which includes a seven-point procedure to observe in applying tires to drop center tims. This includes the following warnings: "Caution: Under no circumstances should the pressure exceed 20 pounds in two-ply tires and 40 pounds in all others. Pressures in excess of these may cause the tires to blow out and injure any person near it." Unfortunately, this brochure is not widely circulated; not one of the tire or tractor dealerships involved in the six accidents had even heard of this brochure and were not aware of this warning.

We provided such warning to one dealership, and, furthermore, prescribed a procedure that would not expose the operator to a personal hazard if the bead did blow off the rim, such a blowoff did occur without personal injury. The dealership demonstrated to the distributorship that it was necessary to use more than 40 pounds per square inch inflation pressure to force the beads properly out against the rim flanges.

In addition to the six accidents which we have investigated, other such accidents have been reported to us or been reported in newspapers. The total of such accidents with large agricultural tractor tires must be many times the number of such accidents that have come to our attention.

In the interest of eliminating this hazard entirely, we will exchange information with other parties having a similar interest. The tire manufacturers may have taken some steps in the right direction, but we have not had the opportunity to learn of more than two such steps taken by one tire manufacturer. The accidents investigated by this organization have resulted in litigation, which is still in progress. Therefore, these written comments are as much as we may reveal at this time.

Thank you.

CHAIRMAN HARTMAN: This concludes the morning session.

If I could just take one minute here so we can set up the afternoon session.

Is the representative from Massey-Ferguson here? Deere & Company? Mr. Charles R. Crook from Des Moines? The American Society of Agricultural Engineers? How about the representative of Ag-Tronic, Inc.? How about Mr. Robert A. Geiger? Ford Motor Company will be here, I know. How about Sunnyside Seed Farms and how about Mr. Zink?

Now, I have one request from White Farm Equipment Company, other than those listed on the program this afternoon. Unless other developments occur, we will be able to carry out our agenda this afternoon and have our informal give-and-take discussion.

We are due back at 1:30.

(An adjournment was taken at 12:07 until 1:30.)

AFTERNOON SESSION 1:30 p.m.

CHAIRMAN HARTMAN: May we come to order.

There may be some in the room now who were not here at the beginning of the morning session. I will not repeat my statement except to say we will adhere to the agenda this afternoon to the best of our ability. We have had just two people who wanted to appear who were not on the published agenda. We accommodated one this morning, the gentleman from the University of Nebraska, and we had White Farm Equipment and we will accommodate them this afternoon. If there are no others who want to appear, we will close the record on that so we can complete our meeting this afternoon.

As I mentioned, at the close of the session this afternoon, for those who voluntarily—and I hope there are many of you—want to remain behind for an informal give and take discussion, there may be questions. If those who have presented views are able to remain behind and wish to do so and those who feel they have questions remain, we who are charged with preparing a report for the Congress may learn much in the process.

One other point. One or two of you have asked about obtaining a copy of the transcript. The answer to that as I know it is this: we will put a copy of the transcript for viewing in our docket room in Washington on the fourth floor of the NASSIF Building. Because of the real short time available and lack of resources we are not reproducing the transcript. If you wish a copy of the transcript, you must make whatever arrangements you are able to make with the court reporters, and they are sitting down here (indicating).

I don't know what those arrangements might be. That will be entirely up to you.

Let us continue.

Next on the agenda is the Massey-Ferguson, Inc., Company of Detroit. I have here Mr. R. W. King, Chief Engineer, Detroit Engineering Division, Detroit, Michigan. We have allotted thirty minutes for you.

Mr. King.

MR. KING: Mr. Chairman, I am here to offer for your consideration a paper that I have prepared on behalf of my company, Massey-Ferguson, in my capacity as chief engineer, Detroit Engineering Division of our company. We do all the tractor engineering for North American in our Detroit operation.

Rather than read this paper in its entirety, because it is quite long, it seems preferable to me at this time to simply summarize the intent of the paper with the expectation and understanding that it will become a matter of record of this meeting and so become available for interested parties to read at their convenience.

In this paper we have attempted to describe those product developments and associated engineering activities in which Massey-Ferguson has been, and continues to be, engaged as these activities relate to agricultural tractor safety.

I should comment that while there have been some unique safety related Massey-Ferguson developments, perhaps best exemplified by the introduction of the Ferguson System of implement mounting and control, in the main our experience and activity probably share much in common with that of other farm tractor manufacturers in this country.

Farm tractor safety is a broad subject. Its main elements, if you will, and these interact in many ways, can perhaps be categorized as follows:

(1) The physical design characteristics of the machine itself;

(2) The immediate environmental conditions in a given operating situation; and

(3) The aptitude, training, and attitude that the operator brings to that situation.

Our paper deals principally and primarily with the first of these three elements, namely, the design characteristics of the farm tractor itself. We have taken the approach of attempting to place the present level of technological achievement in historical perspective by tracing the evolution of improved safety characteristics over the past three or more decades. This might be quite interesting to add, I think, and very fair to add there have been very few categories of mobile equipment in that period which have experienced so rapid a rate of evolutionary change and improvement as the farm tractor.

The intent and effect of some of the specific changes which have been introduced through the years by our company and others have, of course, been exclusively for safety purposes. Very often, however, safety benefits have been the concomitant of product changes which also have other justifications and resons for coming into being. Please do not misinterpret them. This does not mean that safety has been a secondary consideration in the farm tractor industry or that safety benefits have been achieved only as a fortunate by-product. Such is not the case.

In the paper we are submitting we have attempted to trace the design evolution of farm tractors which were once generally unstable, uncomfortable, inefficient, noisy, and difficult to operate. These earlier tractor designs bear little resemblance to those representative of today's production machines.

For a proper appreciation of the functional requirements which significantly influence the general configuration and detail mechanical design of the farm tractor, an understanding of the tractor-implement relationship is essential. This was touched on by speakers this morning. We have attempted to deal with this subject in our paper. The tractor by itself performs no useful function. It must operate in combination with one or more of an ever-increasing number of specialized agricultural implements and machines. For each of these implements or machines the tractor serves as the prime source of energy to accomplish one or more tasks involving pulling, pushing, lifting, transporting, controlling, providing auxiliary mechanical or hydraulic power, as well as many other functions.

In assessing the level of product safety provided by today's farm tractor, it is also necessary, it seems to us, to fully understand the beneficial contributions to safety made by the many developments which have taken place in the major components and systems making up the complete machine. Again, as several of the speakers pointed out this morning, this extent is considerably beyond and is much more complex than just roll bar, safety frame, and composure considerations. Each of these subjects is a complex matter in itself and deserving of careful attention by all of you. In the paper being submitted we have attempted to treat these subjects and to do so with particular emphasis on the effect of these advancements on operator comfort, convenience, and, most importantly, on safety.

Any objective and comprehensive evaluation of the degree of product safety inherent in the farm tractors being produced in this country today requires that consideration be given to the following subjects which we have attempted to cover in our paper:

The tractor-implement relationship;
Present day tractor chassis configurations and relations of the past;
Wheel and tire equipment;
Transmissions;
Engines;
Steering systems;

Braking systems;
Power-take-off drives;
Hydraulic systems;
The operator's station and controls, which, of course, is a complex subject in itself;
Seats;
Lighting equipment, and others.

Our paper also discusses areas affecting operator safety in which engineering efforts are now being concentrated in our particular company.

Finally, the paper considers briefly the current state of voluntary industry standards. These are standards which the Managing Director of the American National Standards Institute in his speech last December characterized by saying no industry was covered by better standards than farm equipment. It is our opinion that a highly satisfactory degree of product safety is assured by voluntary compliance with these standards developed and codified by men with the necessary experience and competence under the auspices of the ASAE and the SAE.

Mr. Chairman, with those very brief comments, I would like to submit our paper on the subject.

Thank you, gentlemen.

(Mr. King's Full Statement Follows:)

I. INTRODUCTION

I have been asked by Massey-Ferguson Inc. to summarize for you those product developments and associated engineering activities in which our company has been engaged as they relate to the broad subject of agricultural tractor safety. The involvement of our company in efforts to improve the safety and efficiency of our tractors extends well into the past and, of course, is continuing today.

I sould hasten to add, however, that my remarks are not intended as a "pat on the back" for our particular company, but rather to present a background review of the subject of tractor safety as we see it and to briefly outline our efforts in the design and engineering areas relating to product safety. Our experience is probably fairly typical of that of other tractor manufacturers in this country.

In the material that follows I will not take the time to discuss or analyze the available statistical data relating to tractor accidents inasmuch as I am sure that, in the course of this meeting you will have this information presented to you. Suffice it to say that the tractor accident data available to us are being continuously used as an indispensable guide in all of our product safety improvement activities.

II. EVOLUTION OF FARM TRACTOR DESIGN IN RELATION TO OPERATOR SAFETY

A. Historical Background

It is probably fair to state that there are very few categories of mobile equipment which have experienced as rapid a rate of evolutionary change as that which has characterized farm tractor design in the past 30 years or so. Therefore, it would seem worthwhile to survey very briefly some of the more important changes that have taken place and their impact on the problems of tractor safety.

Tractors of 30 years ago were generally of relatively short wheelbase and lacking in longitudinal stability, making them prone to overturning backwards under some operating condition. Prior to the introduction and general acceptance of rubber tires for farm tractors, the driving wheels were equipped with steel lugs which resulted in an effective ground contact point well ahead of the rear axle centerline. This characteristic, coupled with the generally short wheelbase and unfavorable center of gravity location, resulted in a very short dimension from the tractor center of gravity to the effective ground contact point of the driving wheels. The net effect of these unfavorable dimensional factors, aggravated by the fact that, in certain conditions, the lug equipped large diameter rear wheels provided virtually unlimited tractive capacity, was a dangerous propensity to overturn backwards.

During the 1930's the "all-purpose" farm tractor configuration was developed and subsequently received very widespread acceptance. This type of tractor was characterized by the so-called tricycle front wheel arrangement in which a single front wheel - or, alternatively, two front wheels placed side by side - was located on the centerline of the tractor. While well suited to the crop cultivation and corn harvesting practices of that period, this type of tractor configuration is considerably less stable from the standpoint of overturning sideways than the four wheel configuration.

Virtually all implements used with these early farm tractors were drawn behind the tractor by means of a drawbar or tongue. In many cases the effective hitch point of the drawbar at the tractor was located at a considerable distance above the ground line and this further aggravated the overturning tendency.

Steering generally required considerable hand wheel effort and generally provided a high degree of reversibility or "kickback" force to the steering hand wheel when the front wheels unexpectedly encountered a side reaction. At the same time the steering mechanism often involved a high reduction ratio so that a considerable number of degrees of hand wheel rotation were generally required to achieve a given turning angle at the front wheels. This made steering response slow and maneuverability poor.

The traction clutch on early tractors was usually hand operated and could not be disengaged as rapidly or easily as the foot-operated clutch on today's tractors. Brakes were generally erratic in behavior and usually provided minimal effective braking torque.

There was little similarity in location and arrangement of the various operating controls from one make of tractor to the next. The operator generally sat on a seat which was adapted from those used on horse-drawn riding implements and which was located well to the rear of the drive axle centerline. The operator's platform, or station, as we know it today was virtually nonexistent. Rear fenders to protect the operator from the rear wheels were not generally provided as standard equipment.

In summary, most tractors were generally unstable, uncomfortable, difficult to operate, noisy, and embodied many other shortcomings which left much to be desired from the standpoint of operational safety.

B. Tractor Design Changes Which Have Significantly Increased Basic Operating Safety

The preceding description of the typical farm tractor of 25-30 years ago is, of course, very sketchy and over-generalized. Hopefully, however, it provides some background against which to assess the importance, from the standpoint of increased product safety, of those design features and improvements which I will now briefly describe. In each case these product improvement areas are listed because of their significance to tractor safety. These same improvements, in addition, have selectively contributed to increased productivity, efficiency, versatility, economy, and other desirable characteristics.

1. Tractor-Implement Relationship

A farm tractor by itself performs no useful work; it must operate in combination with one or more of an ever increasing number of specialized agricultural implements and machines. For each implement or machine the tractor serves as the prime source of energy to accomplish one or more tasks involving pulling, pushing, lifting, transporting, controlling, providing primary or ancillary mechanical or hydraulic energy, and many other functions.

For many years the farm tractor was conceived of primarily as a mechanical replacement for draft animals; it merely pulled an agricultural implement in the same manner as horses or oxen had done for years. The concept of integrating the tractor with the drawn-behind implement to provide an implement attached to, lifted, transported and controlled by, and integrally operating with the prime mover was introduced by the Massey-Ferguson Company. This concept, generally referred to as the Ferguson System, has had a profound effect on the evolutionary development of the farm tractor. Ferguson's three-point linkage mechanism for attaching and integrating tractor with implement has now been adopted by nearly every major tractor manufacturer.

The primary reason for the initial development, as well as the ultimate success, of the Ferguson System of implement control was to make possible the production of a low-cost, efficient, maneuverable, light-weight tractor particularly suited to the depth control of integrated, mounted implements. In this system the implement weight and soil forces were utilized to increase the effective weight on the driving wheels of the tractor and produced significant improvements in operating efficiency.

Equally important, however, this concept of integrating tractor and implement has also had far-reaching beneficial effects on safer tractor operation. Because our company considers this matter of considerable importance, I would like to comment here briefly on some of the safety benefits of the Ferguson System of implement attachment and control.

Most of you, I am sure, are familiar with the general characteristics of the three-point linkage system of attaching an implement in a flexible, but close-coupled, relationship to the tractor. The geometry of this implement mounting linkage is such that, when a ground engaging implement suddenly hits a buried obstruction (rock or stump) producing a horizontal impact force of large magnitude, the effective or "virtual" hitch point for the implement is momentarily located ahead of the front wheels of the tractor and only slightly above ground level. The resulting instantaneous effective draft force and its line of action on the tractor thus produce a negligible overturning moment about the tractor rear wheels as compared to a similar situation when a conventional drawbar-pulled implement strikes an obstruction.

Theory and experience have also demonstrated that the method of attachment of mounted implements makes it virtually impossible with most mounted implements to overturn the tractor backwards in situations other than those involving impacts.

The widespread adoption of the Ferguson System of implement mounting has brought other safety advantages which include the following:

(a) A close coupled, mounted implement (as opposed to a towed implement) makes the tractor more maneuverable and better able to avoid hazardous terrain while working the soil.

(b) Improved maneuverability with mounted implements in transport (carried) position at the headlands at the edges of fields permits the operator a wider margin of safety in avoiding contiguous steep embankments, roads, etc.

(c) Transport of a mounted implement on the highway is safer than in the case of pull-type equipment.

2. Changes to Tractor Chassis Configuration

Many changes have taken place in recent years in basic tractor chassis configuration which have contributed substantially to safety. Wheelbase have been increased and better weight distribution between front and rear wheels has been achieved, both of which have increased longitudinal stability. The four wheel chassis arrangement with wide tread front axles has become the dominant configuration resulting in greatly improved side-wise stability, as compared to the previously popular tricycle chassis type.

Much has been said about the adverse effect on stability resulting from a relatively high center of gravity, which is a consequence of the need to obtain adequate crop clearance. However, the height of the center of gravity is significant only in relation to the wheel tread or lateral and fore-and-aft spacing of the wheels. For example, a sufficiently wide wheel tread provides excellent lateral stability even with a relatively high center of gravity. Today's farm tractors provide a wide range of adjustable wheel treads to suit crop row spacing requirements and the type of implement being used. The wider tread settings available, combined with the adjustable four wheel front axle configuration that now predominates, provide lateral stability superior to that of earlier design tractors.

3. Beneficial Effects of Rubber Tires

All modern farm tractors are fitted with rubber tires. Rubber tired rear driving wheels considerably enhance longitudinal stability, as compared to older tractors with lug equipped steel wheels, in that the maximum tractive effort is definitely limited by the adhesion, or traction coefficient, between the tire and the ground surface.

4. Transmissions

Modern farm tractors are equipped with transmissions offering a greater number of working speeds making it possible to more precisely match ground speed to the work being done. This largely eliminates the need to operate at speeds greater than are desirable or necessary and thus gives the operator better control of his vehicle while at the same time achieving better utilization of available engine power.

The availability today of a variety of power shift transmissions, permitting changes in ground speed "on the go," has further promoted safety by permitting the operator to adjust travel speed to meet changing ground conditions.

5. Engines

The engines fitted to today's tractors are smoother running and deliver usable power over a wider RPM range, further enhancing the operator's ability to match travel speed to the work to be done. Increasingly sophisticated engine and muffler design has significantly reduced vibration and noise for a given engine power level. These improvements have contributed to a reduction in operator fatigue and discomfort, both of which have an indirect but definite effect on operating safety.

In addition, the predominance of diesel engines in today's tractors has considerably reduced the fire hazard associated with gasoline power plants.

6. Steering

Approximately 82% of the tractors produced by Massey-Ferguson today are equipped at the factory with power steering as standard equipment, In addition to reducing steering hand wheel effort to a level comparable with automotive vehicles, power steering effectively eliminates the "kickback" to the hand wheel of severe and unexpected forces imposed on the front wheels of the tractor by rough terrain.

7. Brakes

The great majority of tractor models offered by the industry today are equipped with brakes of the fully enclosed, self-emergizing type, completely protected from the ingress of moisture and dirt. They provide effective, smoothly modulated stopping power with a very high degree of fade resistance, even with the tractor heavily weighted and loaded.

On many of the tractor models offered by the industry today the brakes are oil immersed and oil actuated for even greater effectiveness, reliability, and fade resistance. On the three largest models produced by Massey-Ferguson, the braking action is power assisted and equipped with a hydraulic balancing mechanism which permits the independent right and left brakes (required for tight turning in the field) to be equally applied for uniform stopping at higher travel speeds, even if the two individual brake pedals are depressed unequally.

8. Power-Take-Off Drives

An additional safety feature widely available on today's tractors is the live or independent Power-Take-Off drive providing control of engine driven implements which is independent of the transmission clutch controlling the forward motion of the tractor. The independent Power-Take-Off controls are actuated with little or no effort - in many cases they are power actuated requiring only finger tip movement - which adds to safety by requiring virtually no effort or change in position on the part of the operator in order to actuate them.

9. Hydraulics

One of the outstanding developments in modern farm tractor design has been the very widespread adaptation of hydraulics to provide effortless lifting, lowering, adjusting, and controlling of both mounted and pull-behind implements. Implement control mechanism which automatically maintain a preselected depth or draft load of a ground engaging implement are available from all major tractor manufacturers today.

This widespread use of hydraulics for the control of implements offers the great safety advantage of permitting the operator, with finger tip effort, to raise, lower, or otherwise control his implement without turning in his seat and while devoting his full attention to steering his tractor. He can also simultaneously apply his brakes or actuate his transmission clutch pedal as required.

10. Operator's Station and Controls

The operator's station of today's farm tractor represents a very great improvement over the tractor of not many years ago. The platform area is uncluttered with all controls grouped for optimum efficiency and safe operation. Considerable attention and thought have been given to the addition of mounting steps and hand holds and the use of non-skid surfaces for the platform itself. Amply proportioned fenders are provided as standard equipment to protect the operator from the driving wheels and any debris that might be thrown up by them.

On all of the larger tractor models produced by Massey-Ferguson the steering wheel column can be adjusted both for length and angle of tilt to accommodate all sizes of operators. This is a definite safety feature in that, in combination with the adjustable position seat, it permits near optimum relationship of the operating position of the driver to his controls.

11. Seat

The seats available on today's tractors are another area in which considerable progress, with attendent safety advantages, has been achieved. Adjustments to accommodate different operator size and weight are universally available. A great deal of effort has been devoted to the development of mechanical spring or air-oil suspension systems with built-in dampening devices to minimize the jolts resulting from operation over rough terrain.

12. Lights

Some 25% of all tractor fatalities occur while driving on public roads. Providing adequate lighting and marking is, therefore, of primary importance in reducing the number of such accidents. Tractors produced by Massey-Ferguson are equipped at the factory with a complete set of lights and markings fully complying with the latest specifications of the Uniform Vehicle Code of the National Committee on Uniform Traffic Laws and Ordinances. These lighting and marking devices include the following:

(a) Two fender mounted flashing amber warning lights visible from the front, side, and rear of the tractor.

(b) Two rear reflectors.

(c) One rear mounted combination red warning and rear work light.

(d) Four adjustable forward facing lights for road travel and for night work.

(e) Bracket for mounting Slow Moving Vehicle sign (the SMV sign itself is installed by the dealer).

This lighting equipment is standard on all MF tractors with the single exception of our smallest economy tractor (constituting less than 2% of our total tractor volume) where the lights are sold as optional equipment.

III. OPERATOR COMFORT AND CONVENIENCE - EFFECT ON SAFETY

While the effects on safe tractor operation of fatigue, discomfort, inconvenience, and noise are indirect and not readily amenable to statistical analysis, there is little question but that these factors have an important influence on the occurrence and frequency of accidents. This inter-relationship has been well established in safety studies dealing with the operation of other types of machinery.

We believe that very substantial gains in safe tractor operation have been made within the last few years through the widespread acceptance by farmers of the following technological developments:

1. Power steering.
2. Effective brakes.
3. Improved seats.

4. Improved tractor and implement controls which are characterized by optimum location, standardized direction of movement, and reduced actuating effort required.

5. Reduction in levels of noise and vibration, particularly through the development of enclosures with environmental controls (ventilation, noise and dirt exclusion, heating, air conditioning, etc.).

IV. SPECIFIC AREAS AFFECTING OPERATOR SAFETY IN WHICH DESIGN AND ENGINEERING EFFORTS ARE BEING CONCENTRATED

Statistics show that approximately 60% of tractor fatalities are the result of overturn accidents and that approximately 25% of tractor fatalities occur while traveling on public roads. Design improvements aimed at preventing or minimizing the consequence of such accidents are obviously the most significant areas in which continuing efforts should be concentrated.

I have previously discussed the safety benefits which have already been achieved by the evolutionary changes in tractor chassis configuration and design. While the likelihood of tractor overturns has been much reduced by these improvements, operators still can and do upset tractors. Massey-Ferguson, as well as other tractor manufacturers, has developed and offered as optional equipment for some years safety frames and seat belts, and their effectiveness in preventing fatalities has been clearly demonstrated.

In addition, considerable attention has been, and continues to be, devoted to the development of fully enclosed cabs with the inherent strength characteristics required to protect the operator in the event of an overturn accident.

Massey-Ferguson is continuing its efforts to further improve design details which are aimed at enhancing operator comfort and convenience. These improvements can make important contributions to operator safety through reduction in fatigue and by permitting the operator to devote his major attention to maneuvering and operating his tractor.

Considerable attention has also been devoted to the development of the best possible vehicle lighting and marking devices. I have already noted that virtually all Massey-Ferguson tractors are equipped at the factory, as standard equipment, with lighting systems and mounting provisions for the Slow Moving Vehicle sign which fully meet the standards of the Uniform Vehicle Code.

While less important numerically than highway accidents and overturn accidents, those involving the Power-Take-Off drive line are also receiving close design attention. All Massey-Ferguson tractors are factory equipped with PTO shaft shields and further significant improvements are under development with respect to the implement end of the PTO drive line.

V. COOPERATIVE EFFORTS WITHIN THE FARM EQUIPMENT INDUSTRY TO DEVELOP STANDARDS AND RECOMMENDED PRACTICES AFFECTING TRACTOR SAFETY

In the course of this meeting I am sure you will hear a great deal about the progress that has been made within the farm equipment industry in the development of voluntary standards dealing with farm tractor safety. Therefore, I do not propose to go into this matter in any detail. However, any discourse, however brief, on what has been achieved over the past several decades in the development of safer farm tractors would not be complete without some reference to the influence of these industry standards.

Mr. Don Peyton, Managing Director of the American National Standards Institute, remarked in a speech delivered in December of last year that no industry was covered by better standards than those applicable to farm machinery. There is no doubt in my mind that much of the success our company has enjoyed in the manufacture of safe and efficient farm tractors has been made possible in large measure by the development of a set of voluntary standards, universally recognized within our industry, dealing with safety matters, as well as with the interchangeability between tractors and implements produced by different manufacturers.

It is our opinion that a highly satisfactory degree of product safety is, in fact, assured by compliance with these standards, developed and codified by men with the necessary experience and competence, under the auspices of the American Society of Agricultural Engineers and the Society of Automotive Engineers.

(End of Submitted Material.)

CHAIRMAN HARTMAN: Thank you.

Next on the list, although we are fifteen minutes ahead of the schedule, is Deere and Company.

Would you like to introduce yourself?

MR. MASON: Mr. Chairman, my name is Ralph Mason. I am Vice-president of Deere and Company. I am responsible for the manufacturing of John Deere farm equipment and consumer products in the United States and Canada.

We appreciate this opportunity to make a statement at this hearing on the subject of agricultural tractor safety.

In a few minutes I will introduce my associate, Mr. Keith Pfundstein, Manager of the Product Safety Department at Deere and Company. Our product Safety Department under the management of Mr. Pfundstein is a staff function responsible for developing and coordinating a comprehensive corporate effort to assure safety in the design and use of all John Deere products. This responsibility includes keeping management informed about needed programs and policies pertaining to product safety and about how well we as a company are performing.

Mr. Pfundstein's department works closely with the product design engineers to see that the safety retains the highest priority among design objectives. However, this main responsibility for safety design decisions rests with the individual factories, each of which has its own product safety committee.

I would like to make some introductory remarks and then ask Mr. Pfundstein to address the subject of agricultural tractor safety in greater detail.

The technology of farm equipment is a unique and highly sophisticated discipline. For example, tractors must perform effectively in combination with a great variety of implements to do the many demanding tasks. Designing for safety in field applications requires complete understanding of how the tractor and implement interact and must take into account the great variety of functional requirements of the jobs to be done.

The technology of agriculture is also very dynamic and innovative. New applications in machine accommodations are constantly being evolved by the industry many times in cooperation with the government, universities, and other agricultural research programs. These underlying characteristics of the industry need to be thoroughly understood because the degree to which they are taken into account will determine the success of any safety program which may be developed.

Our industry is proud of its achievements in self-regulation with respect to tractor safety. John Deere is proud of the role it has played over the years in contributing to these achievements. Things that can be done to machinary are, of course, only a part of the over-all problem of safety. You can make sure the machine is designed so it doesn't create unnecessary hazards, and you can see to it that unavoidable hazards are shielded or minimized in some other way. You can analyze all the things the operator is going to have to do when he operates the machine and then make sure that you design the machine and the controls so he can do these things safely and without fatigue. You can work hard on dependability and quality control so accidents won't be caused by failure of components. Manuals can be supplied which acquaint the operator with all aspects of the machine and caution him in areas where safety judgments are required.

It has been and will continue to be John Deere's aim to do all of these things effectively and to continue to improve our performance.

At this point I would like to ask Mr. Pfundstein to present some recommendations and conclusions from our company.

Thank you, Mr. Chairman.

MR. PFUNDSTEIN: Mr. Chairman, inasmuch as most of the important points that were covered in our preparation, our material, have already been covered, what I would like to do, as Mr. Mason indicated, is simply recap for you the conclusions in our paper, which has been handed to the reporter.

We are of the opinion that the farm equipment industry has done much in the safety design of its products and the promotion of safety generally on the farm. We are proud of this record of achievement for the industry and the contributions that Deere has made to it.

We suggest that one of the most significant steps in the reducing of farm tractor accidents on the highway would be uniform application throughout the states of lighting and marking devices as contained in the lighting and marking industry standard and in its parallel in the current uniform vehicle code.

Bearing in mind I am reading only the summary and conclusions, moving next to roll protection, we suggest that the most effective role for the government to play at this time would be the development of an aggressive education program promoting acceptance in use by farmers of roll protective devices. There are some reasons why it might not be appropriate or necessary to remove the farmer's freedom to make his own decision on this protection.

In view of the progress made by our industry in product safety activities, the power-take-off shafts, and in our continuing efforts on the problems associated with PTO, we see no need for government involvement in this area. Other aspects of farm tractor design for safety, in our opinion, need not be the subject for government regulation mainly because we believe the industry's own program is effectively applying current technology to each of these problems.

We think the most desirable roles for government to play in this entire field of tractor safety are to help us direct our future safety engineering efforts by gathering better accident and injury information, see that better farm safety education is provided, and enlarging the body of knowledge we have on human factors as related to farm accidents.

Now I would like to take just a moment to emphasize an observation which Mr. Mason made in his introductory remarks, that the technology of farm equipment is a unique and highly sophisticated discipline, and the designing for safety in field applications requires complete understanding of how the tractor and implement interact. Further, a great variety of functional requirements for the jobs to be done must be taken into account.

If this study by the Department of Transportation concludes that some programs for federal tractor safety standards should be adopted, we feel that program just require two things: first, a supporting staff of long experience in the specialized field of farm technology, and the closest contact and cooperation between government and industry. We think both of these are highly important.

It will be essential that full use be made of the body of experience developed in the industry's own standards program, which, I think, has been very well covered this morning by several previous speakers. Because the technology of agriculture is very dynamic and innovative, any standards promulgated must be expressed in performance requirements rather than any specific design specifications, very important.

In thinking through of what our recommendations should be concerning a possible program for government tractor safety standards, we have been impressed by a basic fact of life, the imposition of a mandatory standards program on any complex and dynamic technology, and certainly ours is that, involves significant costs in terms of time spent by both government staffs and their industry counterparts. Because of agriculture's great need for full interchangeability among machines of different sizes and makes, and because no one of us can foresee tomorrow's developments, standards can also have cost in terms of inflexibility and inhibited innovation. Where regulations effectively meet an important need, these costs may be worth paying, perhaps, but such a program should be embarked upon only when the pay-off in increased safety is quite clear and sure.

Mr. Chairman, that completes my formal remarks.

(Mr. Pfundstein's remarks that were summarized follows:)

Highway accidents are a serious problem in our society. I, therefore, would like to begin with some remarks about reducing farm tractor accidents on the highway. In recent years, the farm tractor in this country has appeared on the highway with increasing frequency. No doubt, this is occasioned in part by the rapid growth in the size of farming operations and in part by new highways which have fragmented some farm lands.

The farm equipment industry has recognized that slow-moving vehicles such as farm tractors, create a special safety problem on the highway for automobiles, trucks, and busses operating at much higher speeds. Our industry has thoroughly assessed this problem, together with representatives of the National Committee on Uniform Traffic Laws and Ordinances and has developed a Lighting and Marking Standard which covers farm tractors (ASAE S279.4 equivalent to SAE J137). This standard has now been paralleled in the farm machinery portion of the latest Uniform Vehicle Code. The lighting and marking called for by this Standard are designed to alert the motorist to the presence of a slow-moving machine which must be approached with caution. Included in this standard is a slow-moving vehicle emblem (SMV), effective in daylight as well as at night, which our industry helped develop and promote. This symbol has received widespread recognition through state legislation and through voluntary recognition and acceptance growing out of various promotional campaigns. Studies conducted by several states with aggressive safety promotional programs show that the SMV emblem makes an important contribution to reduction of farm-tractor-involved accidents on the highway.

It is Deere's recommendation that uniform application of the industry's lighting and marking standard, and the parallel portion of the Uniform Vehicle Code, be an important objective in the federal government's search for improved highway safety. Uniformity of lighting and marking throughout the country can make a contribution to the reduction of highway accidents with slow-moving vehicles, and this uniformity can also prevent unnecessary cost to the customer resulting from regulations that vary from state to state.

It should be recognized that while the information we have about farm tractor accidents involving other vehicles on the highway is far from adequate, it tends to show that the major factor in these accidents may be operator misjudgment, particularly that of the driver of the other vehicle. It would appear that the misjudgment occurs in many instances even though the tractor has been recognizable as such for a significant amount of time and distance prior to the collision. It appears, therefore, that in addition to appropriate lighting, marking, or anything else that can be done to the tractor itself, there are other aspects of the causes of tractor highway collisions that need to be dealt with in order to reduce these accidents further.

While collisions with other vehicles are probably the biggest cause of highway accidents, tractors running off the road is almost as important. Analysis of this problem and attention to it in the design and construction of rural roads where most tractor accidents occur is therefore also an area where a major contribution might be made to tractor safety.

Because we really don't know very much about why many of these highway accidents occur, we recommend government sponsored research into the nature and cause of highway accidents involving slow-moving vehicles.

Tractor overturn is the most significant segment of fatal accidents connected with farm tractor operation. As a result, overturn protection has received increasing attention in recent years, and rightly so. Deere has pioneered in this field and has protective frames available for all farm tractors which we manufacture today (except certain special duty vehicles). In almost all tip-over situations that may be encountered, these frames will limit the side or backward tip to 90 degrees. It is this limitation of roll which provides the greatest protection against serious injury. However, in the event of overturn beyond 90 degrees, these frames also maintain a zone of safety for the operator. Our experience indicates that the use of a seat belt offers worthwhile additional protection, both in the field and in highway collision-type accidents. A seat belt is included with all John Deere protective frames.

Our industry has developed two performance standards for protective frames (ASAE S305.2 and ASAE S306.2, equivalent to SAE J333a and J334a). John Deere frames meet the requirements of these standards and are offered as optional special equipment. We have made these frames optional for several reasons: (1) In some cases, the farmer-customer is purchasing the tractor for a use involving minimum hazard of overturn; (2) A frame as it must be designed to be effective, may, under some circumstances, interfere with the customer's use of the tractor; (3) The cost of a protective frame adds significantly to the cost of a tractor. In view of these customer-oriented concerns, we do not consider it the prerogative of Deere, as a manufacturer, to deny the customer his choice. Deere has, however, put a great deal of effort into publicizing the protection offered by our protective frame and seat belt.

Another means of providing overturn protection is through a cab having sufficient strength to function as a protective frame. More and more tractors are now being equipped with cabs for operator comfort and efficiency as well as for safety reasons. Here again, our industry has developed a performance standard for overturn protection capability in cabs (ASAE S336, equivalent to SAE J168). Deere strongly advocates overturn protection and a seat belt in cabs in compliance with the industry standard. Unfortunately, however, the structural requirements for overturn protection add significantly to the cost of the cab. Nevertheless, once the farmer has decided to purchase a cab, we hope he can be persuaded to buy one which incorporates overturn protection.

I have pointed to several considerations which may influence the farmer away from buying the safety frame or cab designed to provide overturn protection. We suggest the government should not overlook these thoughts in any considration of whether or not to assume the prerogative of making overturn portection mandatory.

Deere feels that the best way to achieve increased use of roll protection without imposing requirements to which the agricultural community might object, is through an aggressive safety educational program by government on the personal safety advantages of roll protection. We believe that this approach, together with the expected trend to increased purchase of cabs, will lead to a significant increase in the acceptance of overturn portection.

In the past, the power drive shaft from tractor to implement (PTO) was a significant source of accidents, but recently the number of such accidents has been greatly reduced. Our industry has progressively upgraded both design and the industry standard for the PTO coupling, which is the area of prime concern. We are currently field testing a design to incorporate further improvements. Shielding which is effective, durable, and will not be removed by the farmer (one of the main problems of shielding in the past) is now a reality. While certain problems remain, we hope we are on the verge of solving these. We understand this subject has been analyzed in a technical paper which will become a part of the record of this investigation.

In view of the industry progress in minimizing the problems related to these PTO couplings, we do not think government regulation would make a significant further contribution to this area.

The potential injury causes I have discussed so far are, in our judgment, the most important ones to concentrate on. There are, of course, many other kinds of accidents which occasionally occur and which we must try to minimize by good design. However, we do not believe there is a need for government to play a role in these areas other than by helping with safety education and by collecting better accident information so we can direct our engineering efforts more effectively. We think this for the following reasons:

1) The industry has taken seriously the problem of designing for safety and dealing effectively with it.

2) Industry can respond to needs more quickly and effectively than the government standards program and with less danger of inhibiting innovation.

3) Our best information indicates that only a relatively small number of injuries are related to any one of these sources.

We believe that the greatest contribution the government can make to farm safety would be the development of a program for gathering better accident and injury information and for better farm safety education. A great many accidents appear to be the result of operator error, and for this reason government involvement with the promotion of safety education to a greater degree, merits top priority action. An additional area, as we see it, for government participation is basic research into underlying Human Factors data that would be pertinent to farm equipment design similar to some of the work NASA has done related to its space program. Government support is needed for this type of costly research, such as that being conducted at Purdue University on one phase of farm tractor controls in relation to operator capabilities. Results of such research are especially needed for incorporation into engineering school curriculums.

In conclusion and summary, we are of the opinion that the farm equipment industry has done much in the safe design of its products and the promotion of safety generally on the farm. We are proud of this record of achievement for the industry and the contributions Deere has made to it. We have suggested that one of the most significant steps in the reducing of farm tractor accidents on the highway would be uniform application throughout the states of Lighting and Marking devices as contained in the Lighting and Marking Industry Standard and its parallel in the Uniform Vehicle Code.

In regard to roll protection, we have suggested that the most effective role for government to play at this time would be the development of an aggressive educational program promoting the acceptance and use by farmers of roll protection devices. We have indicated some reasons why it may not be appropriate or necessary to remove the farmer's freedom to make his own decision on this protection.

In view of the progress made by our industry in the area of safe design of power drive shafts, and our continuing efforts in this regard, we see no need for government involvement. Other aspects of farm tractor design for safety, in our opinion, need not be the subject of government regulation, mainly because we believe industry's own program is effectively applying current technology to these problems.

We think the most desirable roles for government to play in this entire field of tractor safety are to help us direct our future safety engineering efforts by gathering better accident and injury information, seeing that better farm safety education is provided and enlarging the body of knowledge we have on Human Factors as related to farm accidents.

(End of submitted material)

If time permits, and I believe it does, I would like to just highlight for you--and I have given a copy of this also to the reporter--something that we find very interesting in studying this whole tractor safety and farm machinery safety problem.

Perhaps a few in the room are acquainted with the work that Dr. Chauncey Starr has done at the University of California, Los Angeles, entitled "Social Benefit Versus Technological Risk". I will admit I had to read this about five times before I could understand it. It brings into the technical aspects of our kinds of problems, not specifically farm machinery but into our kinds of problems, the social benefits that people accept or fail to accept as reasonable. And he has quantified this. To those of us who are used to quantifying things as engineers, I think this is a very worthwhile study.

We thought it was so significant to the kind of thinking that must go into the plans for a country like ours or a company like ours, or even for us as individuals, we have spent enough time in our company to do the research to insert into Dr. Starr's analysis and study the farm tractor. If I may just take a moment, I would like to recommend this as good reading for you, and also show you just a brief bit of what our conclusions showed when we put the farm tractor into the schedule of other items.

The things Dr. Starr covered included these. Before I mention those, let me back up just a moment. His study considers both the risk of accident on a fatality basis, because that is where the better information is available, and the social benefit derived from that acitvity, expressed in dollars. It covers such things as hunting, skiing, riding in a car as a passenger or a passenger on a commercial airplane or flying in a private aircraft.

It is important to note that his analysis presents the subject on the basis of the number of people involved in that activity, the number of hours which they are exposed to this activity, or involved in the activity, in relationship to the risk of fatality. This is the core of the essence of what he is really trying to say.

The findings come out in this fashion: starting with general aviation, flying your own airplane, if you will, or flying a private aircraft, commercial aviation, motor vehicles, skiing, hunting, farm tractors, these are the areas of activity that I speak of. The comparison shows that skiing and riding in an automobile have almost precisely the same risk of fatality. Some of us possibly in the room are skiers. Maybe it hasn't occurred to us that the risk involved, according to Dr. Starr, is very similar to the risk of the fatality involved in automobiles on our highways, two and a half times the risk of driving a farm tractor. Skiing or riding in an automobile are shown to be two and a half times the risk of fatality of driving a farm tractor, based on the number of people involved in those activities and the number of hours which they are exposed or are involved in those activities.

One final comment, which I think might be interesting. I hope it isn't disconcerting. Riding on a commercial airplane is five times as dangerous as driving a farm tractor.

However, seriously, if we are to assess the problems in this country in terms of all product safety, we feel this gives us a good insight or certainly provides insight into some of the means by which society and we, as engineers, managers, supervisors, must relate as we assign priorities of effort and cost to the prevention of accidents in these various areas.

Thank you very much.

(The comparative risk finding referred to follows:)

Comparative Risk of Fatal Accident

	Fatalities per Exposed Person per Million Hrs. of Exposure
General Aviation	35
Commercial Aviation	2
Motor Vehicles	1
Skiing	1
Hunting	1
Farm Tractors	0.4

(Dr. Starr's paper and Deere & Company farm tractor addendum retained for a time in the docket room of the National Highway Safety Bureau.)

CHAIRMAN HARTMAN: Thank you, Mr. Pfundstein.

I would like to try once again. Mr. Anson Johnson, Keokuk, Iowa, is he in the audience?

Now Mr. Charles Crook. Is Mr. Charles Crook here?

By all rights he has the right to appear at 2:30, so I will call his name again.

Mr. Butt, A. S. A. E., would you be so kind as to appear now rather than forty-five minutes from now?

MR. BUTT: Yes, sir.

CHAIRMAN HARTMAN: Mr. J. L. Butt, Executive Secretary, American Society of Agricultural Engineers, located in St. Joseph, Michigan.

MR. BUTT: Thank you, Mr. Chairman.

I think I will save you just a few more minutes of the allocated time given us. We are preparing a technical paper on this subject which will be forthcoming later, so our presentation today would be to bring out some points which we would not normally include in that technical paper.

So that you may anticipate how the presentation may proceed, we have our comments divided into four parts. The first is the introductory comments, secondly a brief description of A. S. A. E., how it is made up and its capabilities, thirdly, current A. S. A. E. programs relating to safety, and finally some concluding comments.

Introductory and Background Comments.

The 6,500 members of the American Society of Agricultural Engineers are prepared to assist the Department of Transportation, drawing upon the broad range of experience and capabilities of its diverse membership, in conducting the Department's study of agricultural tractor safety.

Secondly, representatives of the Agricultural Safety Committee and other Society officers are currently preparing a technical paper at the request of National Highway Safety Bureau staff representatives, and our presentation today will reemphasize our concerns relative to the agricultural safety problem and present our capabilities, current programs, and plans for making significant contributions toward a safer and even more efficient agriculture.

Secondly, A. S. A. E, Who Are We?

No. 1, we are fortunate in having a diverse and unique membership representing many viewpoints and experiences, in large part the result of the great wisdom and judgment of Congress in establishing land-grant universities, the Federal Extension Service, and the Smith-Hughes Vocational Training Programs. Brought together under the A. S. A. E. umbrella are the following groups of engineering specialists:

1. Research engineers from every land-grant university in the continental United States;
2. Teachers and administrators from every land-grant university and many other universities;
3. Research workers and administrators from the United States Department of Agriculture and other branches of federal and state governments;
4. Extension agricultural engineers, including those responsible for agricultural safety programs at the various state and federal extension offices;
5. Engineers directly engaged in farming and farm management enterprises;
6. Engineering editors of leading agricultural and engineering magazines;
7. Design and application engineers for the farm equipment manufacturing companies;
8. Design, application, and service engineers for electric utilities, food and feed processing plants, irrigation companies, farm building manufacturers, agricultural chemical companies, and engineers from many other diverse companies and organizations serving or representing the agricultural community.

As can be seen, within our Society many viewpoints are available and brought to bear on problems of an engineering nature facing the agricultural industry. Engineering talent from these diverse backgrounds is brought together through the committee structure and in pursuit of the objectives of A. S. A. E.

As a technical Society we furnish a medium for free and critical review of various problems, and challenge our membership in bringing together the best engineering minds available for developing working solutions to these problems.

As a technical Society representing many interests, we do not develop Society positions or advocate to our membership that they take certain positions regarding individual legislative or political issues. We do, of course, encourage our membership to become personally involved in the great issues of the day, and we devote Society publication space and program time toward communicating various viewpoints and rationale for the enlightenment of all members of the Society.

The third portion of the presentation, and the longer one, deals with A. S. A. E. programs relating to safety.

First, is the organization of our safety committee. In 1941 the Society established an Agricultural Safety Committee to coordinate the safety aspects of its many committees and programs. These programs are directed toward farmstead safety and safety in the home as well as tractor and equipment safety.

Secondly, the A. S. A. E. program relates to education. A key aspect of our program has been in the field of educating for safety. This includes sponsorship of technical sessions relating to safety, introduction of safety into college courses, encouraging demonstrations relating to safety, distribution of safety publications to interested individuals, distribution of talks relating to safety, and publication of articles relating to safety in the Society's publications. These efforts are multiplied many fold when put to use by various members through their own contacts with farm people in their work, or through their publications.

The third one is our program relating to standardization. During the years A. S. A. E. has developed and approved many standards relating to safety. I have listed in the paper some examples, nowhere all-inclusive, but to indicate the scope and range of these.

"Construction, Installation, and Rating of Equipment for Drying Farm Drops";

"Single-Phase. Rural Distribution Service for Motors and Phase Converters";

"Minimum Standards for Irrigation Equipment";

"Design Values for Livestock Fallout Shelters";

"Designing Buildings to Resist Snow and Wind Loads";

"Lighting and Marking of Agricultural Equipment and Industrial Equipment on Highways";

"Full Shielding of Power Drive Lines for Agricultural Implements and Tractors";

"Operator Protection for Wheel Type of Agricultural and Industrial Tractors";

And so on. I won't read the entire list.

The fourth aspect of our program is our current tenure plan. Early in 1969 the A. S. A. E. Executive Committee requested the Agricultural Safety Committee to develop a ten-year plan for safety, the goal being to develop and seek implementation of a program planned to reduce fatal accidents in agriculture by 50 per cent by 1980. We believe a concerted plan can greatly accelerate progress toward major reduction of the twenty-five hundred work-related fatalities reported in agriculture in 1969 of which approximately one thousand were related to agricultural tractors.

Fifth is a committee approach to this plan. Representatives of our Agricultural Safety Committee, composed of safety specialists, teachers, researchers, designers, from U. S. D. A., universities, and industry, have been meeting almost monthly since December 1969 to pull together known information and statistics for evaluation of causes of accidents and to assist them in establishing priorities for reducing agricultural accidents. The committee is also identifying areas where additional information is required to make effective decisions so that priorities and responsibilities for corrective action may be assigned.

A two-day workshop has been scheduled by the committee for October 13 and 14 in St. Joseph, Michigan, at A. S. A. E. headquarters to finalize priorities and to prepare a suggested plan of action for review by the Executive Committee of A. S. A. E. and subsequent presentation to the Society membership at our national meeting in Chicago this December.

Mr. Chairman, at this point we would like to invite representatives of the National Highway Safety Bureau to participate in this workshop meeting, if this can be arranged and if your schedule will permit.

And then the concluding statement.

No. 1. We know that our capacity to produce cooperative efforts in the area of safety will work and that effective contributions are being made. We attribute this success in no small way to the diversity of responsibility and experience represented among our membership.

No. 2. The problem before us is a difficult one because of its complexity and many interrelating factors and considerations. No single action, or even a combination of several actions, will produce the desired end result, that of complete elimination of deaths and accidents in agriculture. But by working together, and by bringing together an adequate information base which will permit the application of the best engineering expertise available, and by developing effective implementation programs based on facts we believe a very significant acceleration of progress can be achieved.

We in A. S. A. E. are dedicated to that end result and as Executive Secretary of the Society, I assure you that I speak for our full membership in pledging complete cooperation and assistance to the National Highway Safety Bureau and others toward this end within the limits of our resources.

Thank you, Mr. Chairman.

CHAIRMAN HARTMAN: If there are people here who did not previously register--by "register" I mean leave your names, so that we have an idea who attended so that we have a pretty close tabulation on interest. I would appreciate it if you would do so before you leave this afternoon.

Is Mr. Charles Crook here?

I note that the representative for Ford Motor Company is here. This is a little out of order. We are more than an hour early. Would it be out of order to ask if you would like to come forward now? I have here Ford Motor Company, Mr. Bert Andren, Assistant General Manager, Product Development, Ford Tractor Operations.

MR. ANDREN: Thank you, Mr. Chairman.

Am I heard well?

You have asked us to discuss agricultural tractor accidents and what might be done to further reduce their frequency and severity.

Ford Motor Company, as a manufacturer of agricultural tractors, will speak today about what has been done in tractor design to reduce accidents and injuries associated with our products.

Ford Motor Company entered the tractor business more than fifty years ago primarily to utilize its technology in automobile production to ease the labor burden of farmers. But even then easier farm labor meant safer farms. The equipment in existence at that time was big and cumbersome, usually.

The first tractor designed by Ford was light, relatively efficient, and had no exposed belts and pulleys. That tractor could only pull one-bottom plow or a small implement, relying on its improved utilization of horsepower for efficiency.

Because our company had a basic interest in making the farmer's life easier and more productive, we had a basic parallel interest in producing the best possible machine, which also means a safe machine. We think it well at this time to point out that there is more to tractor safety than simply accident-prevention devices and safety shields. A tractor with a power capacity matched to its anticipated work requirements and with properly designed controls, including transmissions, brakes, and related devices, mechanisms matched to its power, is a much safer machine than one with inadequate horsepower, inefficient transmission of that horsepower and marginal brake capacity.

Mr. Chairman, I had intended to enumerate some of the numerous things that Ford has done, but for the record, on your transcript, in light of the statements of others, perhaps I should omit them.

CHAIRMAN HARTMAN: It is up to you.

MR. ANDREN: Will you bear with us in a little bit of propaganda to advertise our statements.

Based on field reports and its own testing programs, Ford improved the safety design of its tractors through the years. In the 1930s, for example, Ford made some of the following basic improvements to increase the efficiency and safety of its tractors:

We introduced the internal hydraulic system and three-point hitch, which contributed to reducing the hazard of backward upsets by redistributing the pulling burden on the tractor and making it easier and safer to attach and control the implements;

Second, we moved the operator's seat forward to provide for greater visibility;

We eliminated the hand-crank and installed the first safety start switch so that the tractor could be started only with the transmission in neutral;

We added pneumatic tires and improved the manual steering system for safer and easier operation:

We also offered adjustable tread-width front and rear wheels which enabled the tractor to more closely match ground operation requirements and thus, of course, contributed to stability and safety.

In the '40s the company recognized the farmers were using their tractors for more and bigger farm jobs, thus reaching toward the upper limits of the capacity of these machines to perform safely. In response Ford offered higher working horsepower and introduced the four-speed transmission, which permitted the tractor to operate more efficiently and safely in each workload power range. Ford also provided lights as standard equipment for the first time.

During the next decade Ford offered additional design improvements in efficiency and safety:

First, a hydraulic system that operated independently of the PTO, power-take-off system;

Second, specially designed wheel weights that could be used whenever necessary to increase traction and improve stability;

We had power adjusted rear wheels that made it easier for farmers to adapt the tractor quickly to load and work requirements and unique ground conditions;

We made further improvements in seating;

And we introduced power steering;

Another innovation was a power shift transmission, which permitted shifting on the go without stopping the tractor as load requirements varied.

In the decade that has just passed, Ford continued to make safety improvements by:

Adding new horsepower ranges, largely up;

We also improved braking, including hydraulic disk brakes, and improved power steering;

We also improved wheel spacing and offered low center of gravity models for special applications, such as roadside mowing;

We further improved transmissions in both control and in ability to meet widely varying field operating conditions;

There was further improvement in implement coupling systems and we offered differential locks;

We also offered flashing safety lights and slow-moving vehicle emblems for highway use;

Major advances were also made in seat construction and springing, seat adjustment, mounting assists, platform size, slip resistant surfaces, and the design and location of gauges and controls, all, of course, with the idea of making it easier and more convenient and, therefore, safe for the operator.

We also offered safety frames and seat belts and dust-free air conditioned safety cabs.

Ford's attention to safety design in the beginning was primarily in answer to field problems encountered in this new application of power to farming. Over the years safety design has become an integral part of each product program.

In 1961, when the company decided to coordinate its tractor operations on a world-wide basis, an international Safety Engineering Committee was established to review proposed tractor designs and assess the requirements of the markets served. Our Tractor Operations Safety Committee reviews the safety implications of specifications for all product changes and new products and makes sure that these comply with established and practical safety requirements and recommendations.

Under my direction our engineers and product planners consider and review all safety-related product features consistent with the functional characteristics of each particular product. Such features are to reduce the risk of personal injury to operators, helpers, service personnel, bystanders, and other users of Ford Tractor Operations products. Thus tractor safety has been integrated into our design and engineering programs for many years and consideration has been given to possible changes in components or systems that improve the safe reputation of our tractors. The end result is that we are now making available to our farm customers features that we believe are practical and that have significance in safety performance.

Ford believes it is important to point out that the body of statistical information available on the safety performance of tractors in the field is not specific about the age of the units and thus may not reflect the effect of safety improvements adopted in recent years. Nor is the data specific about the actual causes of accidents, whether they result from operator carelessness, poor maintenance, lack of skill, machine overloading, or removal of built-in safety devices.

We believe a key element in reducing accidents on farms is adequate operator training. In this area, Ford, as a manufacturer, has made definite efforts to do what it can to encourage its farm customers to learn and practice tractor safety at all times.

One of the most obvious ways for us to do this is with safety reminders and safety warning decals on the tractor along with clear operating instructions and control identification. We also make safety instructions and warnings an integral part of each Ford tractor owner's manual. The Bureau already has been furnished with copies of these.

In addition, we have operated two dealer training farms, one for more than a decade and one a few years less than that. A portion of each formal training program is a short course in the safe operation of a tractor. More than twelve thousand dealers, members of dealer organizations, and tractor customers have been through this training program.

There is little beyond this that Ford, or any other tractor manufacturer, can do in this vital and critical field of safety training. We feel this is an area which calls for some kind of a nationwide program much like automobile driver education.

Against this background, and for the record, Ford Motor Company's position in regard to the objectives of these hearings is as follows:

Ford Motor Company welcomes the assistance of the National Highway Safety Bureau in helping to further the cause of safety on our country's farms. As does the Congress, Ford believes that the Bureau's already considerable experience in highway and vehicle safety makes it the logical agency in the federal government to examine and evaluate all information relating to farm safety and to undertake such additional research as may be necessary.

Because we believe the Bureau will find, as the manufacturers already have found, that the available statistics are not sufficiently detailed as to age and condition of tractors, competence of operator, and related factors, Ford would support a recommendation by the Bureau to the Congress that the Bureau be authorized and funded to develop the necessary additional statistical studies.

Ford further would support a request by the Bureau to the Congress for additional time to carry out the study mandated by the Congress in Public Law 91-265. Ford's belief that additional time is needed is based on the view that insufficient time has been available for an adequate study as the legislation granted in the Bureau's authority was not signed into law until last May 22. The funds have only recently become available. In effect, the Bureau is left with only a few months in which to develop the statistical and engineering data upon which to make its determination concerning the necessity for and the feasibility of regulation.

Since the bureau's own position, as reported in the Federal Register, is that "Recommendations for corrective action and proposed legislation should be supported insofar as possible by evidence to substantiate such recommendations," we feel this additional time will be vital in developing the necessary substantiation.

Thank you.

CHAIRMAN HARTMAN: Thank you.

Now, I believe, we have the firm of Ag-Tronic, Inc., Hastings, Nebraska, Mr. Dale Carpenter. We have allotted twenty minutes at your request.

MR. CARPENTER: Gentlemen, my name is Dale Carpenter. I cover the eastern half of the United States for Ag-Tronic as their District Sales Manager.

I know most of you in this room are familiar with Ag-Tronic, and you are familiar with SMV emblems. I recognize that major tractor manufacturers use our emblems. If they do not use ours, they use one comparable to them. We manufacture SMV emblems at Hastings, Nebraska. We are the world's largest manufacturer of emblems.

I know some of you in this room might ask, what is an SMV emblem. You have heard other manufacturers speak of SMV. It is an emblem designed to be on a vehicle moving twenty-five miles an hour or less. When I asked in the State of New York what do you call a thoroughfare, they said anything that resembles a cow path that you can get a tractor on.

The emblem is manufactured direct to SAE standards. We adhere strictly to this. All emblems that are manufactured on SMV emblems has to be conformed to these standards, there can be no deviation from it. The reason for the necessity of the emblem, we felt, was the problem of a slow-moving vehicle with a fast-moving object coming up directly behind it.

I grew up in farm states and farm areas, and moved to St. Louis about twenty years ago. I have seen tractors demolished by an automobile hitting them at no higher impact than thirty miles an hour. I have seen tractors torn in half. Consequently, the SMV emblem was born, born out of necessity for the safety of the operator as well as the traffic behind the tractor. This problem was taken to the states. I am happy to say at this time we have twenty-two states with mandatory legislation. The balance have legislation that is pending or permissive legislation.

Some of the results in these states that have mandatory legislation are very surprising, and I would like to briefly cover them with you.

In the State of Michigan, which was the first state to have mandatory legislation, in the year 1966 they had four fatalities. This was before the law was passed. They had fifty injuries, they had forty-one property damages. They had a total of other types of accidents of two hundred fifty-three, and they had ten fatalities and ninety-nine injured and a hundred forty-four property damages. The law was passed in 1967. We had sixty-five for the total number of accidents and one fatality, thirty-five injured and fifteen property damages. This is on rear-end collisions on this first one. All other types we have two hundred thirty-five, thirteen fatalities, five injured, one hundred twenty-seven property damages, for a total of three hundred.

In 1968 in the State of Michigan they had fifty accidents. They had no fatalities, they had thirty-five injured, fifteen property damages. That is from rear-end collisions. Your other types are two hundred sixty-two; they had twelve fatalities, ninety-seven injured, a hundred and fifty-three property damages, for a total of three hundred one.

On rear-end collisions, again, in 1969 they had fifty-two accidents. They had two fatalities, twenty-six injured, twenty-four on property damage.

On your rear-end collision alone on this, your change on this on your total accidents was minus 46 per cent, your injury was minus 36 per cent, and your property damage was minus 51 per cent.

On your other types of accidents for 1969 you have a total of two hundred seventy, you have fatalities of seventeen, you have one hundred five on injury, on property damage one hundred forty-eight, for a total of three hundred twenty-two.

On fatalities there wasn't enough difference to get a figure. On injuries it was plus 2 per cent, and on property damage it was plus 5 per cent.

Your rear-end collisions on farm equipment at non-intersections from 1965 went from 88 to 95, that was in 1966, dropped to 65 in '67, and to 50 in '68, and back to 52 in '69.

I find these figures very enlightening.

I have a film that was made in cooperation with many people to show you this afternoon. I think you will get more from the film than I can tell you here on SMV.

The one thing I want to stress is that the states that have laws passed on this, I have yet to talk to a farmer who is against it. I have yet to talk to an equipment dealer who is against it. I have yet to talk to an implement manufacturer that is against using the SMV emblem. I have yet to talk to a manufacturer, farmer, or user of tractors or farm equipment that isn't geared to the safety program, and the SMV emblem fits into tractor safety. I think this is the first step to sell tractor safety right down the line.

With this SMV emblem tied onto Congress as such, it not only sells the rest of the safety programs that the manufacturers have built into their safety equipment, but also, when a man gets on this tractor, he looks at the emblem and he is safety minded before he steps on.

I would like at this time, Mr. Chairman, to show our film.

(At this time a film was shown.)

CHAIRMAN HARTMAN: I think we are in good shape. What about ten minutes? It is now 12 minutes to 3 by that clock. At 3 o'clock sharp we shall resume.

Thank you.

(Short recess.)

CHAIRMAN HARTMAN: May we come to order.

Is Mr. Charles S. Crook, Jr., of Des Moines, Iowa, here?

I am sorry he is not. He wrote in and asked for time to speak. He described himself as a farm owner, an owner of three farm tractors, and a professional in the field of safety.

We have a little time here. With your indulgence I would like to read into the record four letters received from people who have views on this matter of agricultural tractor accidents, injuries and deaths, but who were not able to be here today. I could put these into the record and they would appear there. On the other hand, since we have a little time and there are people here who might be interested, if you will bear with me and my voice, which is not outstanding for this purpose, I would like to read them into the record.

The first one comes from Mrs. Phyllis Brierty, 1603 Second Street, Boone, Iowa, September 5, 1970, as follows:

> "I have a copy of the news release, 'The Department of Transportation's National Safety Bureau has scheduled a public meeting in St. Louis, Missouri, to discuss problems relating to agricultural tractor safety.'
>
> "Knowing of Congressman Neal Smith's concern, I have over the past several months mailed news clippings to him covering tractor deaths that have occured here in the central part of Iowa. Many of the victims, young adults with families--it is frightening--I do not want to think all these accidents are through carelessness.
>
> "It seems to me the gases and exhaust emitted from diesel powered tractors could be a contributing factor. The operator is only a few feet from the exhaust pipe. We know the components of diesel fuel can cause unconsciousness. I know some tractors are gasoline powered--they could be dangerous, too, especially in certain areas during damp or foggy weather.... the emissions from the engine cling closer to the ground and are slower to dissipate.
>
> "This letter is that you may know of my concern, and with the hope the meeting provides some valuable information for the report to Congress.
>
> "See attached picture.....
>
> "Yours very truly."

The second one comes from Mr. Wendell Bowers, Extension Agricultural Engineer, Farm Power and Machinery, Cooperative Extension Service, Oklahoma State University, Stillwater, Oklahoma, The letter is dated September 11, 1970:

"I have read with great interest your letter of August 25 relative to the public meeting on September 17 in St. Louis to review agricultural tractor accidents. Since I cannot attend this meeting, I would like to have my comments either read at the meeting or incorporated in the appendix of the proceedings.

"The problem of agricultural tractor accidents has received a considerable amount of attention during the past several years. For example, we have had a 4-H tractor project since 1944 whose primary goal was to teach our youth to become safe operators. We also have a number of Extension Farm Safety Specialists in many states whose primary job is to try to make the farm a safer place to live. Both the 4-H tractor program and the Extension Safety Specialist work are under the direction of the Cooperative Extension Service located at Land Grant colleges under an agreement with the United States Department of Agriculture. Our American Society of Agricultural Engineers and the Society of Automotive Engineers have also been very active in providing standards for the design of safer farm machinery in order to reduce the hazard to the operators. We have also had a considerable amount of research such as that conducted at Ohio State University in the development of a slow moving vehicle emblem and some excellent basic farm safety research conducted at the Iowa Institute of Medicine under the direction of Dr. Knapp. I feel certain that detailed reports of all of these activities will be presented as part of this meeting or supplied in writing for inclusion in the appendix.

"Almost anyone working in the area of safety agrees that it takes the proper balance of the three 'E's' in order to have a beneficial effect on the reduction of accidents. Those three 'E's' are Education, Engineering and Enforcement. For the past several years I feel that we have had some very vigorous efforts on the part of education and engineering to try to reduce farm accidents, particularly those dealing with tractor fatalities. Engineering of the slow moving vehicle emblem in Ohio has resulted in the passage of laws in a number of states making the use of this emblem mandatory on farm tractors and slow moving vehicles when they are used on a highway. A survey in Michigan has shown that we have effectively reduced the number of accidents by the adoption of this law. More recently we have had the enactment of the Hazardous Occupation Act by the Department of Labor in which restrictions have been applied to employment of youth under 16 years of age in agricultural work. Part of the Act provides for specific training so youth 14 and 16 years of age can be exempted from certain portions of the Act. In cooperation with the Department of Agriculture, the responsibility for the development and conduct of the training program was given to our Cooperative Extension Service. So far we have trained and certified approximately 2,000 youth in Oklahoma with this program and our surveys show that we have not had a single injury type accident involving the youth we have trained. We feel the safety record of these youth is outstanding and is far better than for the average farmer.

"I have been very much impressed with the way the Hazardous Occupation Act and the accompanying Exemption Training Program has provided us with new tools to complement our educational programs in an attempt to reduce tractor accidents. Our surveys also show that the Hazardous Occupation Act and the Extension Training Program has been very well accepted by the youth involved, their parents, and the employers. My personal feeling is that we should implement and enforce the current Hazardous Occupation Act with the Extension Training Program and give it a chance to prove itself before we impose any more restrictions or standards on agriculture. We have gone along for years with education and engineering in the knowledge that we have done some good but the rate of reduction of accidents has not been acceptable. Now, in the last two years we have come along with some enforcement in the nature of the Hazardous Occupation Act and it has been a real boost to those of us in safety work who feel the need for some leverage in the adoption of our educational programs. I would like to see any further action on the part of our federal government be directed at the support and reinforcement of the current Hazardous Occupation Act and the educational programs conducted by the Cooperative Extension Service.

"Any further restrictions or standards imposed on agriculture by yet another department in Washington at this time would have a very detrimental effect on the attitude of farmers. In fact, it would tend to destroy the effectiveness of current programs. I will strongly urge that we do everything possible to support and enforce the current programs before moving on to any further legislation.

"Yours very truly."

The third one comes from Mr. Richard G. Pfister, Extension Safety Engineer, Cooperative Extension Service, Michigan State University, East Lansing, Michigan. The letter is dated September 2, 1970.

"Thank you for your letter providing information on the September 17 meeting on tractor accidents and corrective measures. I am committed to participate in a conference on that date and will be unable to attend.

"I am contributing to two technical papers being prepared for presentation by other authors. In addition, the attached brief presentation is submitted for consideration at this session. Best wishes for a successful meeting.

"Sincerely,"

The enclosure is headed "Effect of Slow Moving Vehicle Emblems on Collisions into Farm Equipment on Michigan Highways". Since this is in considerable effect similar or very close to what the previous speaker gave, with your indulgence I will just put this into the record without reading it.

(The enclosure referred to follows:)

AFFECT OF SLOW MOVING VEHICLE EMBLEMS
ON
COLLISIONS INTO FARM EQUIPMENT ON MICHIGAN HIGHWAYS[1]

Nearly one thousand rear end collisions involving farm tractors or equipment on public roads occurred in Michigan during the period 1957-1967. Most of these collisions took place during daylight hours, on open highways, with good road, weather and visibility conditions. The slow moving vehicle (SMV) needed to be clearly identified so that incoming motorists would recognize it in time to avoid a collision.

Action

Michigan Public Act 163 (attachment) went into effect in March, 1967. It requires use of a SMV emblem on tractors and machinery, construction and highway maintenance equipment, horse drawn conveyances and other vehicles designed for operation at 25 miles per hour maximum speed, when operated on public roads or highways.

Results Achieved

In September, 1967, a survey was made of 2222 farmers located in 10 counties. Results showed an average of 3.28 SMV emblems per farm or an estimated total of 271,722 emblems on Michigan farms. Over 90% of the farmers said they used the emblem every time they drive a SMV on public roads. A considerable number of farmers owned more than ten emblems, with a range up to 25 emblems per farm.

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[1] Dr. Richard G. Pfister, Extension Safety Engineer, Michigan State University, East Lansing, Michigan. Submitted to the National Highway Safety Bureau for presentation at the public meeting on tractor safety, September 17, 1970, St. Louis, Missouri.

Data compiled by the Michigan State Police indicate the following record of farm equipment accidents over the past four years.

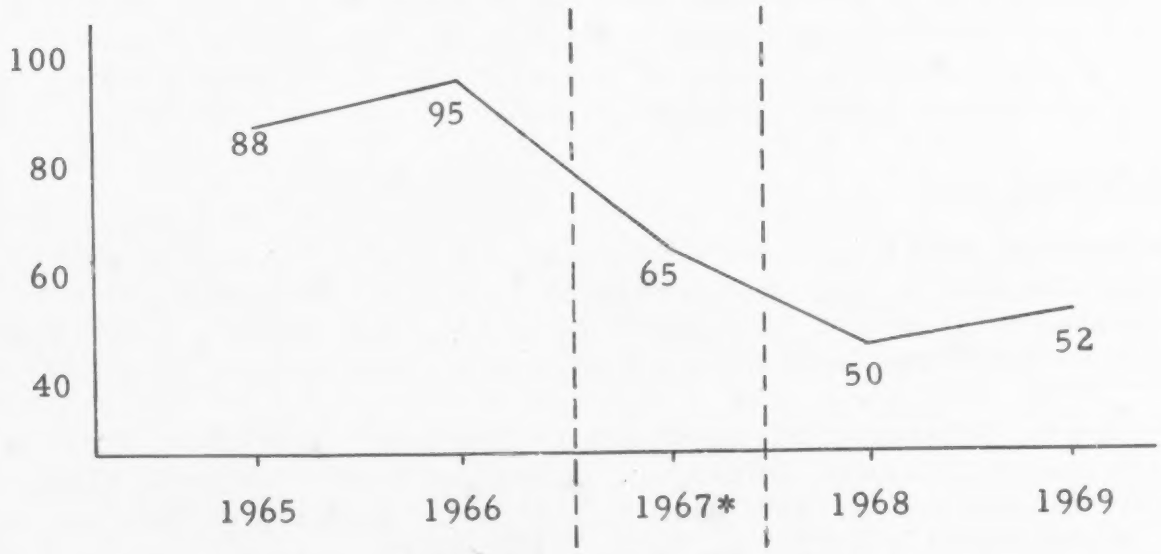
FREQUENCY OF FARM EQUIPMENT ACCIDENTS ON PUBLIC ROADS

	Rear-end Collision (Non-intersection)				All Other Types				Total
Year	Sub Total	Fatal	Injury	Prop. Damage	Sub-Total	Fatal	Injury	Prop. Damage	
1966	95	4	50	41	253	10	99	144	348
1967	65	1	35	29	235	13	95	127	300
1968	50	0	35	15	262	12	97	153	312
1969	52	2	26	24	270	17	105	148	322
*Change	-46%	**	-36%	-51%	+5%	**	+2%	+5%	-9%

* Comparison of 1966 statistics to 1969 statistics. The 1966 statistics provide accident experience the year before SMV emblem legislation went into effect and the 1968-69 statistics provide experience for two years following the legislation.

**Numbers too small to realistically compare by reporting percent change.

REAR-END COLLISIONS INTO FARM EQUIPMENT, NOT AT INTERSECTION - MICHIGAN



* Year SMV emblem law went into effect

This data clearly shows that the frequency of rear-end collisions was reduced 46 percent after the use of SMV emblems became prevalent. In contrast, other types of farm equipment accidents increased 5 percent during this period.

Conclusion

Legislation requiring use of SMV emblems on specified equipment has resulted in excellent compliance and a reduction of almost 50 percent in SMV rear-end collisions on public highways.

Recommendations

1. That SMV legislation conforming with the Uniform Vehicle Code become effective in all states.
2. That manufacturers of slow moving vehicles have SMV emblems affixed to the rear of all tractors and self-propelled machinery before shipping to retail outlets. (Eliminate do-it-yourself safety projects.)

(End of submitted material.)

The final one is from Dr. Horace E. Campbell, M. D., Denver, Colorado. His letter is dated August 28, 1970.

"I will not be able to attend the meeting in St. Louis on September 17 relating to farm tractor safety, and I have nothing to add to what has already been said repeatedly since 1960, i. e., that about 60-70 per cent of farm tractor fatalities result from overturn of the tractor, and these facilities and many serious injuries can be prevented by causing all farm tractors to be fitted with well-designed roll bars and seat belts as original equipment.

"More than this, I would like to suggest that insurance companies be asked to insert waivers in their accident policies denying liability for injuries or deaths in tractor turn-overs and power-take-off injuries in which power-take-off guards are not present and in use, and in which roll-over structures of approved design and seat belts are not present or are not in use.

"I think powerful incentives must be brought into being to assure these well-proved preventives are employed.

"I would appreciate your sending me any documents or reports that emanate from this meeting.

"Yours very truly,"

Next on the agenda, Mr. Robert A. Geiger, Milwaukee, Wisconsin.

Is Mr. Geiger in the room?

This is moving the schedule up again a little bit. Mr. Swanson, would you be prepared?

Sunnyside Seed Farms, Middleton, Wisconsin, Mr. Randall C. Swanson, President.

MR. SWANSON: As a preface to my remarks addressed to the problem at hand, the following statement may establish and clarify my interest and my concern and my experience in the area of farm safety.

I have served on the board of directors of the National Safety Council and was chairman of the Farm Conference of that organization.

I have also served as incorporator, president, and executive secretary of the National Institute for Farm Safety, Incorporated. I have served 25 years as a farm safety specialist, University of Wisconsin College of Agriculture. My experience includes a lifetime of farming. I now devote full time to the operation of my farm and related agri-business enterprises.

My remarks are strictly my own as a farmer and should not be termed as reflecting the views of any organization with which I have been or am now affiliated.

I am sorry the farm safety specialist for the University of Wisconsin, Mr. Jensen, could not be here as he would present the educational philosophy on the prevention of accidents. This morning, Mr. Hatcher from Wisconsin presented the state government enforcement policy, and I represent a farmer's viewpoint.

I have lived long enough to have viewed broad changes in agriculture. My early farm power experiences were with the old horses that would turn by themselves back into the plow furrow and the right corn row. Some were even credited for getting old fellows home from town that might not have otherwise made it.

The change from the one-horse horsepower to over 100 mechanical horsepower in some of the modern tractors is no more spectacular than some of the other technological changes that took place in that era. Large quantities of flammable fuel, poisonous insecticides, along with special machines to complement the power tractor are all a part of the surging agriculture. An agriculture that changed from one man producing food for himself and five others when I was a boy, to food for 11 others in 1935, and for over 40 others today, could well be expected to encounter problems.

With production capacity per man increased almost fourfold in the last 35 years, many adjustments were needed. Safety did not escape the impact and required new approaches and new solutions to many new problems. We are still having many farm accidents that need not happen. I don't claim that any of us on the farm or in professional safety work are satisfied with our record. We should not be satisfied as long as even one person loses his life or receives a permanent injury unnecessarily.

It should be pointed out, however, that we are not alone in the predicament, as every segment of our society is struggling to eliminate these unnecessary accidents. We are all trying to meet the problem in our respective areas and reach the "Utopia" which has eluded all of us, including the Division of Transportation, so far.

On the positive side, let me say I was proud of the progress that has been made in farm safety by farm people themselves, by educational leaders, and by agricultural industry. In every state where farm safety specialists have been employed, a substantial decrease in farm accidents has been documented. These figures are available and have been available for a long period of time.

The significant factor here is that a small amount of money used for intensive state educational programs resulted in a very marked reduction in farm deaths and injuries.

Farm people have been encouraged to assume much of the responsibility for accident prevention. The activity of the adults as well as the positive action taken by the 4-H Clubs, Future Farmer Chapters, and other youth groups, has resulted in a much improved safety record. It is well for us to remember that most of the labor on our farms throughout America is provided by the farm family itself. Over 90 per cent of the farm labor in Wisconsin is provided by the farm family. This significant fact should impress upon us that the safety attitude and the safety practices carried out on our farms will be the decision of the farm family members. This becomes extremely important as the great majority of accidents, not only on the farms but on the highways as well, result from human failures. The attitude of farm people and their desire to do something about farm accidents has been tremendously influenced, as the figures indicate, by the work of the farm safety professional.

Slow-moving vehicle accidents on our highways, largely farm vehicles, throughout the nation stimulated research by agriculture. The result of this research was the emblem identifying slow-moving vehicles. Educational leaders emphasized the value of this life-saving device to the extent that it has been adopted and/or endorsed by 27 states in this nation at this time.

This is only one example of many instances where research and education in agriculture have shared in a project to save lives. The slow-moving vehicle emblem is relatively new, however, its effectiveness has already been documented in at least one state mentioned here a little while ago, the State of Michigan. This information, of course, is available to everyone.

I have many times highly commended the farm machinery industry for their research and their effective safety developments from such research. I commend them here again for such things as the shielded power-take-off, protective guards over chains and gears, improved lighting, power steering, and overturn protection on tractors. These are only a few of the results of the efforts that industry has made to fulfill its obligation to protect the agricultural user. Industry has made many outstanding improvements in both the tractor and other farm machines to protect the life and limb of the operator. It should be noted that these tractors and farm machines of which we speak must operate under a variety of conditions such as hills and swamps, rain and snow, tangled crops, steep hill sides. We are not always favored with a stationary machine standing on a hard surface where conditions can be more easily controlled. These varying conditions to which we have referred increase the hazards to the operator and make our problems in agricultural safety much more difficult. The machinery industry must not only produce a machine which offers safety for the operator, but also a machine that will function under a wide variety of conditions and at a price which the farmer can justify on the basis of its productive value.

Function often requires a compromise with safety. As an example, the varying conditions under which tractors and machines operate requires a relatively high clearance, therefore, a less stable machine. A decision here in design must be made by knowledgeable and practical people. The result much be a machine which embodies the maximum possible safety and still allows the machine to perform the function efficiently for which it was intended.

I could cite many examples of progress measured in reducing loss of life and permanent injury in the field of agriculture. It is my opinion that the last ten years of agricultural safety activity has resulted in a saving of lives and prevention of injury equal to or surpassing the progress made by any other segment of our society. I challenge anyone to refute this statement.

My presence here is prompted by the fact that I see in this directive from Congress the possibility of legislation which may be a hindrance to our continued progress toward a safer agriculture. I am a little confused and highly disturbed over the implications that are contained in the directive to the Department of Transportation. It is difficult for me to understand as a farmer and as a former professional safety worker why an agency such as the Department of Transportation is asked to make such a study. The Department of Transportation, in my opinion, has no expertise to study and report on the problems which are named in the request from Congress. It is only logical that studies which involve technical areas should be carried out by people who have technical training in such areas.

With apologies to those present from the Department of Transportation, I question the advisability of asking a department not familiar with the technical problems of agriculture to make such recommendations. I am disturbed over the outline prepared by the Department of Transportation to which I have had access, as it indicates a review of many technical problems including tractor design which they will investigate. I am also disturbed when a unit of government is asked to investigate an area in which they are not technically prepared.

On the other side of the coin, we have an agricultural department which is basically concerned with agricultural problems including safety that has the facilities to carry out such an assignment. It is rather baffling to me to understand why the Department of Agriculture, which maintains an educational branch, the Extension Service, which reaches the grass root farmers throughout the nation, has not been assigned to report on the status of farm accidents. The Department of Agriculture also has an understanding and a working relationship with industry.

I am further disturbed when I read the Federal Register regarding this study or investigation, that proposed legislation might include licensing, inspection, and permits for tractors. Every state, as far as I know, has a car licensing procedure. I see no place or need for federal licensing or federal legislation at this time. Federal licensing, in my opinion, has no relation to safety.

On my own farm, I operate lands for three-quarters of a mile on either side of U. S. Highway 14. This requires using Highway 14 and crossing it many times. I have no objection to requiring a driver's license of all farmers who operate on public highways. This, however, should be a state prerogative and the licensing machinery of the state should be used to accomplish such a regulation.

In my own case, I require a Wisconsin driver's license of any operator who crosses or uses the highway with our farm equipment. Federal licensing or permits for tractors can make no further contribution to safety in my opinion.

I am concerned also by the implications in this outline that tractors might be inspected and that requirements in the design of a tractor may come from the federal government. There is no evidence in our past record or experiences that federal regulations would improve our safety record. I do not approve of federal legislation that might add to the cost that the farmer must pay for farm machines which might conceivably detract from the function which these machines can perform. There is no evidence that federal regulations or interference would improve the safety of our farms and may be a very costly item.

If a study, an investigation, or an inspection is to be made, in my opinion it should be made by the Department of Agriculture. The directive of Congress delegates this authority to the Department of Transportation. I mush ask my Senator and my Congressman why the Department of Agriculture was bypassed and why the Department of Transportation was assigned to a technical job which they are not prepared to do.

There is much evidence that the Department of Transportation is making a sincere effort to interview agricultural industry and others in the agricultural field who possess expertise in that area. For this I commend them. It still is evident, however, that when the evidence is all collected and the report is prepared, the Department of Transportation will be the judge and jury and that Congress will receive in this report such information as they deem advisable.

As a farmer, I object to this procedure. I do not go to my dentist with legal problems nor do I go to my able attorney for my physical ailments. The record in agricultural safety does not warrant this study and report in the first place, but if it is to be made, the Department of Agriculture, in my opinion, is the proper agency to make it.

I could be more tolerant to such an investigation by a non-agricultural agency if this agency had shown beyond a doubt that they had the answers to the prevention of all accidents. But the Department of Transportation has the same problem that we have in agriculture. They have not solved the killing of 55,000 people on the highways each year; therefore, they may not be the agency to solve the agricultural problem.

The National Safety Council, the National Institute for Farm Safety, the farm families themselves, and the agricultural machinery industry all have a great stake in this problem, and all of them have made and are making a tremendous contribution.

I am confident that progress will continue with all segments of agriculture using their past experiences and their new approaches in a dedicated effort. Let me repeat again, however, that major responsibility rests with the farmers, the farmers must take this responsibility themselves and with their families.

No tractor design and no educational effort will be effective until and unless safe procedures are accepted and practiced by us, the farmers. As an example, in Wisconsin hundreds of Future Farmers compete in a tractor safety driving contest each year. To reinforce my belief and to help in a small way, and maybe to put a little money where my mouth is, my farm presents ten trophies to the district and state winners. We believe that it is the right direction to take in solving our accident problems.

To be a little positive and in conclusion, let me say that I recommend to the Department of Transportation that education has the greatest possibility, as shown by past experiences, of reducing farm accidents;

Two, that federal legislation has no place presently in our safety progress;

Three, that when legislation is required, that it come from people who have the technical knowledge to determine its value and effectiveness;

Four, that appropriations of money, if any, be directed to the Department of Agriculture through their Extension Service where effective programs have already shown their worth; and

Five, that technical problems such as tractor design be left to the people that have years of experience who can balance safety and function in a practical manner.

Thank you.

CHAIRMAN HARTMAN: Thank you, Mr. Swanson.

I have no identification of Mr. Geiger other than Mr. Robert A. Geiger, 1456 North Farwell, No. 3, Milwaukee, Wisconsin. He sent a note saying that he intended to address his remarks to this matter. His note is dated August 27, 1970. He says,

> "I suggest all tractor manufacturers put a MERCURY Incline/ Off Balance SWITCH in ignition circuit. Thus potential upsets would automatically switch off ignition and stop tractor before accident occurs."

Next on the agenda, although moved up, Mr. Carlton L. Zink, from Moline, Illinois.

MR. ZINK: Thank you, Mr. Chairman.

When I wrote in, I had indicated that I might wish to say something if it seemed pertinent. As some of my friends would say, I might want to talk whether it is pertinent or not.

I listened to some of these comments. Possibly for the record, I should give a little bit of my background. I spent 14 years with the University of Nebraska faculty, 12 of those years, 7 years with Firestone and the last four manager of the farm power development production, 18 years with Deere and Company, and the last 16 years directly and personally involved in production safety, development of safety standards, and the dissemination of this information to our various factories. I retired in 1968, and now I am serving as production safety consultant on occasion.

From this background, I would like to offer the following comments. I have just heard a few of the remarks by Mr. Swanson with respect to regulations. I had previously made these little notes that regulations are not all good, regulations are not all bad. I support the position taken today by Larry Hodges of J. I. Case, that regulations should not stifle the engineering ability, the imagination, desire to offer an outstanding product of those individuals responsible for tractor design. Conversely, I am grateful as I drive back to Moline I shall be traveling in a group of vehicles that are required by regulatory action to have head lights, turn signals, and hopefully, if they happen to be slow moving equipment, will have an SMV emblem on the back, not necessarily so since Illinois has not been taking quite that firm a stand.

I shudder to think of what the situation might be if compliance in this latter area was voluntary and failure to comply resulted in no penalty. I hold that farm tractors and equipment should not travel the highways with less safety, or shall we say greater potential hazard than do automobiles, trucks, buses, and the like.

As some of my co-workers may think, you really want folks to spend money, but eventually if the money comes from the farmer and it's his life and ours that we are saving.

Mr. Pfundstein and others suggested we have good lighting standards that would apply to newly manufactured tractors and other agricultural equipment. I am concerned about the hazards presented by tractors and equipment now being used on farms, machines which are 5, 10, 15, even 20 years old. You can be just as dead hitting an old tractor or implement as you would colliding with a new one.

Education was mentioned as one of the three E's. I think education in safety is vital, but it is not a cure-all. Nonetheless, it can be truly helpful. Those states which employ a full-time safety specialist can show a record of accident reduction, not an elimination of accidents, but an improvement in the situation. I urge that the Department of Agriculture be requested to see that each state, in turn, be encouraged to name a full-time safety specialist.

I will stand corrected on this, but it is my impression that currently there are only about seven states that have a full-time safety specialist in their employ.

Communications can be a problem. It is one thing to be understood; it is another, so to speak, that you cannot be misunderstood. So at some risk, I am going to, after talking with George Steinbruegge this morning, this noon, he was talking about standards which apply to overturn protection. He bewailed the fact that he might not have said what he should have said in the way he said it, not that he failed to say what he meant, but some people may not have interpreted in that fashion. I will gamble on trying again for George. I used to occupy a position there. As I remarked, I spent 12 years in that institution. Some of my friends used to say all old Carlton did was sit there and say no. We wanted everybody to put forth a good tractor and to be judged on what they produced. Actually, if they elect to check the crush resistance of cabs at Nebraska and judge them against a standard, if I interpret George's remarks correctly, he feels that the cabs currently offered by the tractor manufacturers far exceed the requirement of the standards.

For example, one of my former co-workers was at the Nebraska State Fair this Sunday before Labor Day and was talking to a vendor who had a cab there for sale which he labeled "crush resistant." On investigation he found that this man claimed to not have heard of standards, did not know what standards were. He said it's a good cab. It makes me think of the old farmer I asked about his cow, the milk that she gave. He said, "She's a good cow, she does the best she can." This cab may not be good enough to give you a haven of safety in case the tractor overturns.

George's philosophy, as I say, to these people that work up to standards, take another look, won't you, please, and at least raise the standards for the cabs up to the standards that are there.

I see him nodding his head up and down, it wasn't sideways, it was up and down. Well, thank you, George, for my trying, you know what I mean, I hope I didn't mislead you and say something you did not want me to say.

I went on to say that George fears that cabs barely meet the standard, that barely meet the standard will not adequately protect the driver under adverse or severe accident conditions.

I have seen pictures of cabs, I have seen some actual cabs, that have been subjected to a free fall type of overturn where they laid the cab down on top of the real wheels. We saw that sort of thing in the movie this morning, what I call the old garden variety, this didn't claim to be crush resistant. But if manufacturers are working without the benefit of being familiar with standards, then we need to do something to make sure they do follow the standards. If the standards as written are not good enough to take care of the loads which are occasionally imposed upon the cabs, which George Steinbruegge maintains by tests that they have run, then we need to raise the standards. Well, so much for that. I hope I still have friends.

If I were to ride in a tractor cab, I would like to have it sustain a ballasted tractor in a free fall at a 180-degree turnover, I wouldn't expect that to be asking too much.

I am also concerned about the responsibility for the use of existing safety features as per current standards on the equipment that is now used day by day on the farm. What does that mean? It is simply that the manufacturer may make the safety device, shielding, of one type or another, for the power take off, the belts, the chains, the gears, and put them on the machine or tractor as standard equipment, but the farmer is not necessarily going to use them.

You say, well, O. K., it's his machine and it's his life, but it isn't necessarily his life because he hires men and who is to say that the hired man is operating a machine that is properly protected. You might say, well, that's no skin off our noses, that is out of our province, but I think it is part of this general pattern that we need to be concerned with safety. After all, the operator is the one that is injured, fatally or otherwise, and I look on this as an obligation that may not be met without regulation. Just as I looked on the automobile lighting as one that we accepted the regulation, now I would be skeptical of acceptance of it on a voluntary basis, and voluntary basis is all that we have. So this is one area to which, I think, some type of regulation, other than self-imposed discipline, which I have somewhat lost faith in, I do not believe is adequate.

Finally, I would encourage the continued co-operation of representatives of industry, from farm organizations, from the land grant colleges, and from pertinent departments of our federal government, all working towards the making a farm a safer place. I would say let us all, as men of good will, provide such engineering, education, and enforcement as to "Before we are through with this safety bis, a farm is the safest place there is."

Thank you.

CHAIRMAN HARTMAN: We have one last speaker who has asked to be on the program, White Farm Equipment, Hopkins, Minnesota, Mr. Arnold A. Skarjune, product engineer. Would you come forward, Mr. Skarjune.

MR. SKARJUNE: I might clarify one thing first, that the White Farm Equipment Company name was formed in the latter part of 1969, referring or regarding to tractors only. The companies involved were the former Cockshutt, Minneapolis-Moline, and Oliver.

Now, as individual companies, the industry working through the Farm Industrial Equipment Institute, we were going to make a statement on the evolution of the farm safety features, but, as it was remarked to me in the audience, everything has been covered, what else is there to say? I can do this, I came prepared in this manner, also, to make nothing more than a summary. So if you would bear with me and through my eyes, look at the tractor safety features, but it would have to be, of course, at a White tractor, as I see it.

The White Farm Equipment Company provides tractor safety features to meet the industry standards as established by the Society of Automotive Engineers and the American Society of Agricultural Engineers.

Tractors are provided with a bracket to mount the SMV emblem when travel on public roads is necessary.

Two amber flashing warning lamps are provided for public road travel. The lamps are mounted so that viewing from the front or rear of the tractor is possible.

A combination red tail/white work light is provided on the rear of the tractor for public road travel after dark.

Two head lamps are provided for after dark public road travel.

Reflective material in decal and stripe form is provided on the rear as well as the sides of the tractor for after dark visibility with light reflected from automotive head lamps.

A farm equipment breakaway connector for a lighting kit on pull-behind equipment is provided on the tractor for public road travel.

A safety switch is provided on the tractor to prevent starting of the tractor while in gear.

Hand holds, skid-resistant steps, platform, and pedals are provided for safe tractor mounting.

Tractor rear wheel guards are provided to protect the operator when the tractor is in motion.

A PTO shaft cap is provided with the PTO shield to be used when the tractor PTO is not in use. Shrouds enclose the fan blade and shields are provided for protection against belts and pulleys.

Hazard warning decals are provided to stress attention to the safety precautions to be taken on different areas of the tractor, and instruction decals are provided for safe tractor operation.

The design and test cost to meet industry standards for tractor roll-over protection with roll bars and canopy or enclosures are absorbed by the company. The roll bar is offered as optional equipment to the tractor user, along with safety seat belts. The tractor enclosure or cab provides roll-over protection on some of our current tractor models. Our future policy is to provide tractor enclosures or cabs with integral roll protection.

Tractor drawbars are located low to minimize the possibility of rear tractor overturn. Tractors with 3-point hitches prevent rear tractor overturn when an implement is attached.

Tractor add-on weights provide tractor stability as well as wheel traction.

PTO engagement and shut-off is accomplished hydraulically on some tractor models. One tractor now employs PTO disconnect for positive shut-off. The disconnect for positive shut-off is under review for all our current model tractors.

These safety features have evolved on farm tractors through self-discipline of our industry.

Other methods are being employed for the prevention of tractor-connected accidents. Tractor operator manuals stress safety precautions when servicing tractors and outline rules for safe tractor operation. Tractor driver education programs that are now active will reduce the number of tractor accidents and injuries. Farm accident study programs in progress in Minnesota and other states will provide factual information that could lead to the reduction of farm tractor accidents and injuries.

As industry, and I think I speak for us all, our objective is to produce safe operating tractors and equipment through the cooperation of our industry associations providing expertise on tractors with regard to safety. Management, design engineers, safety engineers, and test engineers will continue to pool their talents, proficiency, and their time and efforts with stressed emphasis for safety of the farm tractor operator.

Thank you.

CHAIRMAN HARTMAN: We have come to the close of this public meeting, and I want to thank all of you who have come here today taking time from your busy schedules. We appreciate the views and comments, the pros and cons, the different aspects of farm tractor safety because we know they were honestly and sincerely given. All of the papers indicate considerable thought and effort went into them. The record has been made.

Thank you.

(Whereupon, at 4 o'clock p.m., September 17, 1970, the meeting in the above-entitled matter was closed.)

Roster of Attendees

Andren, Bert	Ford Tractor Operations, Ford Motor Company, Birmingham, Michigan
Arnett, Wayne	Land Improvement Contractors of America, Barrington, Illinois
Arp, Harlan K.	International Harvester Company, Chicago, Illinois
Bailey, Robert B.	Ford Motor Company, Dearborn, Michigan
Barrett, Robert L.	Deere and Company, Moline, Illinois
Boudreaux, S. A.	U. S. Public Health Service, Kansas City, Missouri
Brune, Ray	Deere and Company, Moline, Illinois
Butt, J. L.	American Society of Agricultural Engineers, St. Joseph, Michigan
Carpenter, Dale M.	Ag-Tronic, Inc., Hastings, Nebraska
Cavender, Norman	Farm Journal, Inc., Philadelphia, Pennsylvania
Coleman, R. N.	International Harvester Company, Hinsdale, Illinois
Crawford, J. C.	Society of Automotive Engineers, New York, New York
Davis, Owen R.	Allis-Chalmers, Milwaukee, Wisconsin
Dierbeck, John J., Jr.	International Harvester Company, Chicago, Illinois
Falstead, David B.	J I Case Company, Racine, Wisconsin
Feltman, C. R.	3 M Company, St. Paul, Minnesota
Fogarty, Bill	Implement and Tractor Magazine, Kansas City, Missouri

Fowler, William J.	MFA Insurance Company, St. Louis, Missouri
Friedl, John F.	Allis-Chalmers, Milwaukee, Wisconsin
Gellatly, J. A.	O. Edward Kurt and Associates, Royal Oak, Michigan
Goering, Carroll E.	National Association of State Universities and Land Grant Colleges, Columbia, Missouri
Graham, E. H.	Massey-Ferguson, Inc., Des Moines, Iowa
Hall, Garth	Bostrom Division, UOP, Milwaukee, Wisconsin
Hatcher, Harry	State of Wisconsin, Madison, Wisconsin
Henley, Dan	Doanes Agricultural Report, St. Louis, Missouri
Hodges, L. H.	J I Case Company, Racine, Wisconsin
Hove, John H.	U.S. Public Health Service, Cincinnati, Ohio
Hunley, Ed	Electric Wheel Company, Firestone Tire and Rubber Company, Quincy, Illinois
King, Robert W.	Massey-Ferguson, Inc., Detroit, Michigan
Koenig, Donald V.	National Farm and Power Equipment Dealers Association, St. Louis, Missouri
Krey, Marjorie	Deere and Company, Moline, Illinois
Larson, L. W.	U.S. Department of Agriculture, Beltsville, Maryland
Lucy, David C.	Farm Equipment Manufacturers, Association, St. Louis, Missouri
Mason, Ralph L.	Deere and Company, Moline, Illinois

McGary, Wm. J.	International Harvester Company, Chicago, Illinois
Murphy, Weldon O.	J I Case Company, Racine, Wisconsin
Neiley, George	Deere and Company, Moline, Illinois
Obika	St. Louis Post-Dispatch, St. Louis, Missouri
O'Meara, Arthur C., III	International Harvester Company, Chicago, Illinois
Parsons, Marc J.	Ford Tractor Operations, Ford Motor Company, Birmingham, Michigan
Pfundstein, Keith L.	Deere and Company, Moline, Illinois
Pratt, Will M.	Caterpillar Tractor Company, Peoria, Illinois
Randt, L. W.	Farm and Industrial Equipment Institute, Chicago, Illinois
Sacks, N. N.	Deere and Company, Moline, Illinois
See, George L.	Caterpillar Tractor Company, Peoria, Illinois
Skarjune, Arnold A.	White Farm Equipment Company, Hopkins, Minnesota
Steinbruegge, G. W.	University of Nebraska, Lincoln, Nebraska
Sullivan, Herbert D.	International Harvester Company, Hinsdale, Illinois
Swanson, Randall C.	Sunnyside Seed Farms Inc., Middleton, Wisconsin
Urben, Leon	National Safety Council, Chicago, Illinois
Williams, James L.	Country Companies, Bloomington, Illinois
Wilson, Charles E.	U.S. Department of Labor, Washington, D. C.
Wormley, James D.	Farm and Industrial Equipment Institute, Chicago, Illinois

Wuks, H. W.	Deere and Company, Moline, Illinois
Zich, John H.	Ford Tractor Operations, Ford Motor Company, Birmingham, Michigan
Zink, Carlton L.	Consultant, Moline, Illinois

Letters Expressing Views Received Post Public Meeting

The Coats Company Inc.
P.O. Box 817
Fort Dodge, Iowa 50501

September 11, 1970

Dear :

One hazardous facet of farm tractor operation in the state of Iowa is the presence of individual tractors, tractors pulling single and tandem grain trailers, and tractors pulling various implements at slow speeds on primary and secondary roads. Most wagons are equipped with the reflectarized triangle, however this warning device is inadequate when concealed by the crest of a hill, covered with mud or occasionally displayed.

It is the opinion of the writer that all slow-moving farm vehicles should display an electric rotating beacon light visible for 360° at an elevation of ten to fifteen feet above the road at all times while entering, traveling on, and exiting from a public road. In addition, the normal running lights required by trailers, trucks and automobiles should be required.

Meaningful penalties should be prescribed into the law for violators. As you know, the arrogant attitude of some farm operators has created a queue of cars traveling at a snail's pace on fast highways. For every tractor-car collision reported there are probably five incidents where cars have left the road to prevent a collision.

We believe the farmer needs the protection far more than the automobile driver for the automobile may have one tractor exposure in 1,000 miles whereas the tractor operator may have 20 automobile pass him in one mile.

Best wishes for good legislation,

S. J. Siberell
Manager Manufacturing

The Pennsylvania State University
Department of Agricultural Engineering
249 Agricultural Engineering Building
University Park, Pennsylvania 16802

September 14, 1970

Dear :

I appreciate being informed about the public meeting on agricultural tractor safety. Unfortunately, I will not be able to attend this meeting.

In my opinion, present agricultural tractors in the United States do not provide sufficient safety for the operator or satisfactory working environment. The progress in improving the situation is too slow. I believe that watchful interest by a proper authority would provide the necessary incentive for the manufacturers to increase their efforts in this area. Such an authority could also contribute by coordinating the efforts of establishing proper standards for minimum requirements.

My interest in this area originates from personal experience with tractor safety work in Sweden prior to 1963. I have later maintained contact with American tractor manufacturers and the National Safety Council regarding tractor safety and kept informed about developments in Europe. I assume that you have available my paper in the Agricultural Engineering Journal, 1967, and also the paper No. 70-105 on Safety and Comfort Test Program presented at the 1970 annual meeting of the American Society of Agricultural Engineers by Mr. Olle Nordström.

I would appreciate being informed about the progress of your investigation. I may be able to contribute with comments on specific points based on my earlier experience.

Yours sincerely,

Sverker Persson
Associate Professor

Illinois State University
Department of Industrial Technology
Normal, Illinois 61761

September 17, 1970

Dear :

Much to my disappointment prior commitments on campus will prevent my attending the public meeting in St. Louis dealing with agricultural tractor accidents. However, I possess some strong concerns on this topic which I wish to relate. My work and experience in the field of Agricultural Safety leads me to believe that tractor accident problems are many faceted, each requiring diverse considerations for solution.

A study of the first consideration, "... the number of deaths and injuries resulting annually from agricultural tractor accidents...," reveals a problem inherent in the entire Agricultural Safety field, the lack of an accurate, comprehensive, effective farm accident reporting system. Without this information being available, it becomes extremely difficult to assess the magnitude of the tractor accident, or any other farm accident problem, with any degree of precision. Because of the diversity of agricultural enterprises, conditions under which tractors are operated, tasks requiring the use of a tractor, and hazards inherent in each, studies of tractor accidents in one or two locales do not generate data sufficiently comprehensive to generalize the scope of the nationwide problem. Couple this problem with the limited number of researchers currently carrying on studies into farm accidents, and any attempt to accurately quantify the tractor accident problem requires a large amount of guesswork. And when sufficient manpower, funds, and motivation are available to start, and periodically repeat, National Safety Council Farm Accident Survey in all states, this dearth of accident data can and will be alleviated.

Even though comprehensive data are not available on which to base reliable estimates, studies by Pfister in Michigan, Stuckey in Ohio, and Schnieder in Nebraska do shed some light on the scope of the nationwide problem. From these studies it appears safe to conclude that farm tractors, and tractor mounted farm machinery, constitute the single agent most frequently involved in farm work accidents.

When looking deeper at this problem, it seems that tractor accidents may be broken into three major classifications. The first and most serious class of accidents involve those associated with actual in-field tractor operation. Typical injuries of this class result from tractor upsets, noise, entanglement with operating power-take-off, and exposure to exhaust fumes and the sun. The second classification involves accidents arising from the operation of farm tractors and tractor mounted or towed equipment on the public highway. Included in this classification are accidents with other motor vehicle operators or upsets as a result of running off the roadway. The third class of accidents result from tractor storage and maintance; specifically, fires when refueling, storing, or accidents arising from implement hitching or unhitching. I shall leave to other organizations and persons suggestions for engineering solutions to these problems, and direct comments, specifically, at possible educational and legislative solutions.

The safe operation of tractors and machinery on public highways appears to be a problem increasing in magnitude. Sociological and economic trends have forced the midwestern farmer to "get big or get out" of farming. As a consequence, more and larger farm machinery must be operated over longer distances going to and from nonadjacent fields. Couple this fact with the improvement of rural highways, thus bringing about higher automobile speeds, and the probability of tractor-automobile collisions increases drastically. The use of warning devices, such as the slow-moving-vehicle emblem becomes of paramount importance to prevent this type of accident. The value of the emblem in preventing this type of collision has been documented in studies in Michigan and Nebraska. Following enactment of mandatory legislation regarding the use of these emblems, a 47% reduction in non-intersection rear-end collisions with slow moving vehicles was noted in Michigan, and a 45% drop in fatalities from motor vehicle - farm tractor collisions in Nebraska. It must be noted that these results were obtained first by legislation requiring the use of the emblem, followed by an intensive educational program into the purpose and meaning of this device.

A great need exists for the adoption and enforcement of the Uniform Vehicle Code by all states. This code required the use of the S-M-V emblem together with other lighting and marking requirements to protect the tractor operator. However, the adoption of the code must be accompanied by educational programs for these protective devices to adequately serve their purposes.

The danger of tractor upsets as a result of running off the road, or unsafe field operation, make mandatory roll-bar or crush proof cab installation on tractors a serious consideration. Further consideration needs also to be directed to the development and use of adequate rear view mirrors for farm machinery.

Perhaps the most important suggestion I have for partially solving the farm tractor accident problem is in direct line with a statement issued by the State Advisory Council for Farm Labor Safety in New York. In a report issued in June, 1970, the Council recommended that a "... massive and comprehensive educational program, on all aspects of farm labor safety, be developed and carried out as soon as possible." The Hazardous Occupations Order for Agriculture, issued and administered by the U.S. Department of Labor, mandates specific training for hired workers under the age of sixteen. Research should be conducted into the effectiveness of this training, with an eye kept toward improving this curriculum. There also exists, in some educational quarters, the feeling that all tractor operators should be trained, tested, and licensed, before allowing them to operate farm machinery on public highways. In any event, a definite need exists to develop and implement additional training into all aspects of agricultural safety through existing education systems. Effective education must accompany legislation and engineering approaches if we are to reduce the accident frequency and severity rates in our agricultural labor force.

I shall be quite interested in the final results of this study and am willing to provide any further assistance desired by your department.

Sincerely,

Gary Erisman
Chairman of Occupational Safety

National Institute for Farm Safety, Inc.
2 Agricultural Engineering Bldg.
University of Wisconsin
460 Henry Mall
Madison, Wisconsin 53706

September 18, 1970

Dear :

We note in the Federal Register, Vol. 35, No. 163, dated August 21, 1970, that your office is inviting letters from interested people on the subject of agricultural tractor accidents, and that we are asked to submit these statements to your office by September 21, 1970.

The National Institute for Farm Safety, Inc. includes representatives of farm organizations, tractor manufacturers, universities, government agencies, and others interested in farm safety. This organization of professional safety workers is interested in efforts which reduce farm accidents. Many of our members have been employed for several years as full-time safety specialists, program leaders, and directors of safety. The decrease in farm accidents in those states employing full-time safety people speaks for itself.

The National Institute for Farm Safety, Inc. supports the present practice whereby the development of safety standards for farm tractors and other equipment is the cooperative effort of members of the Farm and Industrial Equipment Institute, members of the American Society of Agricultural Engineers, and members of the Society of Automotive Engineers. We believe that the system of voluntary development and voluntary compliance with these safety standards by industry is working well. The standards we now have were developed by individuals with the necessary background to recognize the essential compatibility of the safety features, the function of the machine, and the price that the user can afford to pay. We further believe that federal standards are cumbersome to develop and less likely to be responsive to the technological changes in crops and livestock practices. These technological changes are continually in progress and will in turn require changes in equipment both as to function and as to form.

We approve the enactment of requirements that the operator of a tractor or a self-propelled machine on our highways must have a license to drive an automobile in the state in which he lives. Also, we approve the program that the 14-16 year old operators of farm equipment on farms other than those owned and supervised by their parents or guardian should have special training. We would not approve the idea to require special licensing of operators for each and every type of farm machine nor to require registration and annual inspection of each farm machine. We object to these considerations on the ground that such a program would be tremendously expensive to do, and, from the record of farm fatalities, is not warranted. The loss of lives on our farms is less than 1/50th of that occurring on our highways. This doesn't make one farmer's life any less important but certainly points to the fact that most safety emphasis ought to be on the automobile rather than on the tractor.

The National Institute for Farm Safety, Inc. believes that educational efforts need to precede and to be coincidental with any legislative effort. There will be considerable consumer objection to being forced to pay $200 to $500 more for a tractor equipped with roll-over protection unless the consumer has been convinced that this is something he needs. It is foolish to think that the farm machinery industry can be forced to put safety devices on a tractor without passing the cost on to the consumer. It is economically impossible for the industry to absorb such cost.

We can point to the fact that educational efforts combined with improved engineering are reducing the incidence of farm accidents. Statistics from several states show it is reasonable to assume that an increased expenditure for farm safety education would make the rate of accident reduction more rapid.

It is unfortunate in many respects that the Department of Transportation was designated by Congress to make this study and to evolve recommendations since only a very minor part of the farm machinery accident problem is related to highways, and that is being successfully reduced by the SMV Emblem. The problems of farm machinery safety need the input of people from agriculture who know the facts of machine function, the economic factors of farm life, and the compatibility of safety proposals with these considerations. We hope you will make use of the experts in the field of farm safety to counsel and guide you in this study.

The National Institute for Farm Safety, Inc. would endorse a procedure for uniform accident reporting so that the national statistics are more accurate and helpful.

This letter has been circulated by mail and approved by the Board of Directors of the National Institute for Farm Safety, Inc. and we trust it will receive your careful consideration, and be made a part of the record from which your report will be prepared.

Sincerely yours,

Orrin I. Berge, President

International Harvester Company
Research and Engineering Center
7 South 600 County Line Road
Hinsdale, Illinois 60521

September 21, 1970

Dear :

As an addendum to the material we presented at the Agricultural Tractor Safety Meeting, Mark Building Auditorium 12th & Spruce Sts., St. Louis, Missouri, September 17, 1970, we are presenting the following.

International Harvester has run over one hundred side and backward roll-over tests during the past four years with many different models of our tractors. Based on our tests, we believe the Protective Frame Performance Requirements shown in A. S. A. E. Standard S-306.2, 1970 Agricultural Engineers Yearbook, and S. A. E. Recommended Practice J334, 1970 S. A. E. Handbook, are adequate for the intended purpose. If at any time our information indicates these technical Societies' documents are not adequate, we would feel obligated to so inform these Societies.

For the performance requirements for operator protection as established by organizations dealing with foreign countries or with groups of foreign countries, we suggest contacting the Organization for Economic Cooperation and Development, O. E. C. D. Publications Center, Suite 1305, 1750 Pennsylvania Avenue N. W., Washington D. C. 20006; The National Institute of Agricultural Engineering, Wrest Park, Silsoe, Bedfordshire, England; and Statens Maskinproningar, Ultuna, Uppsala 7, Sweden.

Sincerely,

R. N. Coleman, Staff Assistant
Test and Development Group

Needville, Texas 77461
Rt. 2, Box 19

September 20, 1970

Dear :

I read the article in the paper on the issue of --"License To Drive A Tractor". The article stated that this licensing prospect is only one of several tractor issues that will be important to the future of agriculture. I would like to say that it is indeed important. The Government and laws are helping to push us farmers out of business.

The possibility of licensing and inspecting tractors is one of the most stupid, idiotic things I have heard of.

I have four sons and I am teaching them how to handle machinery. I have a fifteen year old who has been operating combines, cotton picking machines, and four-row equipment since he was twelve. Also, I have a 13 year old son who is learning to do the same. They enjoy using this machinery and can make their own spending money this way. Not only that, but they are learning something which many of our young boys nowadays do not have the opportunity to do - THEY ARE LEARNING HOW TO WORK - or is that something to be ashamed of? We have been complimented time and again because of the way our sons conduct themselves, and the fact that they are willing to work. My younger sons are eleven and five years of age. Please think of this. -I do not want to tell them they cannot learn to drive the tractors because they would not be able to get a license anyway.

In this community there are many young boys who run farm equipment. Do not deprive them of this chance to learn to work and make a little money, especially during the summer months. That is the time of the year when so many of the youngsters get in trouble. They are bored and looking for something to do.

It would do more good to educate drivers of cars, etc., by that I refer to those who will go at breakneck speed to pass farm machinery. Licensing will not help this situation. We are very cautious on the roads. Many drivers who see machinery ahead of them will speed up and take all kinds of chances just to pass.

Also, take it into consideration that the farmer is having a tough enough time without worrying about license and inspection on farm equipment.

Sincerely,

James Freund

Belmont, Ohio

Sept. 21, 1970

Dear :

My views on tractor Safety I have formed for 50 years tractors is made for the level country.

Make them for these Hills make them lower to the ground & longer and wider there will be more weight on the ground.

Cleetrack is wider and lower to the ground. I never saw one of those Cleetrack upset yet.

So if they are wider lower on the ground it will save a lot of lives on these Hillsides.

Your truly a Farmer

Harry Jarrett

Canton, Kansas

Sept 23, 1970

Sirs:

Just read the article in Oct Farm Journal on "Federal Standards on Tractor Safety".

I want to say I am against any laws on tractor safety. I think the manufacturer should try to put as many safety designs on equipment as possible, but I am especially against tractor registration and inspection. We have too many government bureaus already.

I have 11 tractors some of which I haven't used for 2 years - others I use perhaps 20 hrs per year and the top 4 are used about 250 hrs per year.

I believe the rate of accidents compared to the hours of operation is so low as to be nearly impossible to improve.

Especially if all things are considered - one of my cousins died in a tractor accident, but it is believed he died before the accident. Another accident involved an 80 yr old man and the nature of the accident suggests he also could have died first.

Thomas Ratzloff

P. S. Roll bars are the only feature I know of that may be alright, but I wonder whether the operator may take just a little bigger chance, because of them.

T. R.

John R. Klug
Colonial Park
Lebanon, Mo.

Sep 28, 1970

Gentlemen:

I am glad to read in the Farm Journal that Federal safety standards are being considered for tractors. I have lost a dozen good friends killed in tractor accidents and I have always maintained tractors should be safer. Here are some of the things I think should be done.

My main tractor is a Ford 3000 and I drilled a hole in the ignition key, and fasten a nylon line to it and through a ring bolt and the end has a snap that hooks onto my belt. Then if I fall off the motor is shut off.

Secondly, I have a seat belt on this tractor for use when bush hogging, so that if a limb would brush me off, at least I wouldn't be thrown from the tractor and under the bush hog.

Of course roll bars should be on all tractors.

A horn should be on tractors with some way to call for help, perhaps a lanyard so that you could trip the horn to blow a pattern that people would recognize as a distress signal. I will get trapped some day hooking on some implement and it will be 10 hours before my wife will miss me.

A tractor should have a pair of steel bars on the front up as high as the operators head so that he has protection when swinging under trees, and these should be positioned close to the operator so that he can take cover behind them. Perhaps the roll bar can be so positioned to double duty here.

My tractor has an overriding clutch so that the bush hog's momentum will not cause an accident. This simple device costs only $25 and would save so many lives. But most farmer's do not know such a device exists.

There should be protective shields for the rear of tractors for protection while bush hogging.

Power take offs should be shielded, and it be against the law to sell an improperly shielded attachment.

Clutch rods should be internal or shielded. Once I rode up on an unseen stump and the clutch could not be depressed.

The seats of tractors should be of a size and depth that you can't fall out of.

There should be a bar behind the seat so that you can't fall off backwards while trying to lean back and adjust something especially should your foot slip off the clutch.

I have a wide angle convex rear view mirror on my tractor, but try to mount one on yours.

How about a tool box big enough to carry a hydraulic jack, chain, crow bar, etc.

How about a rotating rear warning light such as Highway Depts. use.

I own and operate a Western Auto store primarily, but when I die, probably it will be a miserable death from a tractor.

Pour it on the tractor manufacturers. So it adds $200, the widows would be glad to pay it.

Sincerely,

John R. Klug

How about a mercury switch to warn the operator he is climbing too steep a grade, or at too great an angle - then it could double duty by sounding the distress horn & lights should he overturn.

There should be a lanyard to shut off the engine from the rear, should one be walking behind the tractor and fall into the drive shaft.

APPENDIX C

Wheeled Tractors for Farm Use: Characteristics (Actual or Projected) of Those on Farms, Marketed, and in Dealers' Inventories, 1940-1974: Numbers, Horsepower and Age

NOTE: The Table in this Appendix was prepared by Paul E. Strickler, Agricultural Engineer, Economic Research Service, U. S. Department of Agriculture.

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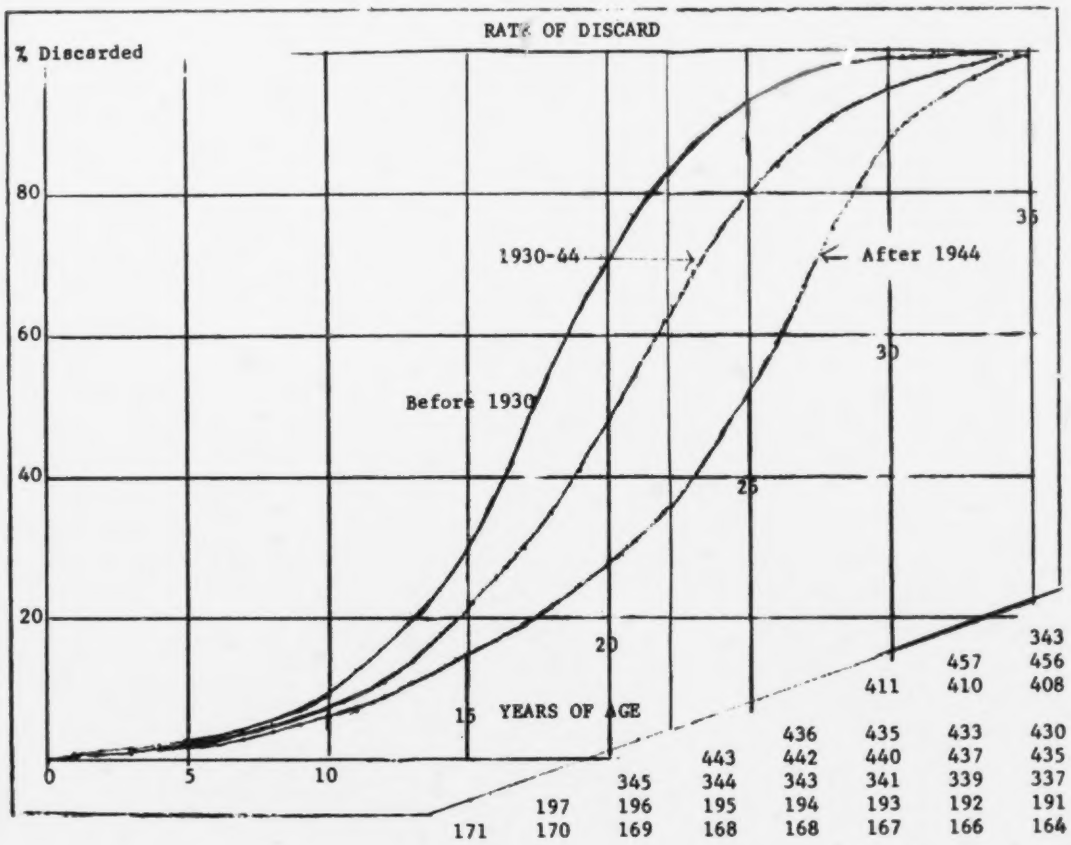
Wheel tractors for farm use: Designated characteristics of those shipped or sold; number remaining in specified years, number of farms, and esti



Year	No. of tractors and h.p.		Number remaining at																
	Thous.	Ave. h.p.	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	195
1974	120	83.0																	
73	123	81.2																	
72	126	79.1																	
71	130	76.9																	
70	134	74.8																	
1969	144	72.8																	
68	158	69.5																	
67	177	68.2																	
66	185	65.9																	
65	162	63.1																	
1964	157	59.3																	
63	155	58.0																	
62	153	56.0																	
61	138	53.8																	
60	124	50.5																	
1959	215	46.2																	
58	194	45.7																	
57	186	43.2																	
56	178	39.6																	17
55	272	40.6																271	27
1954	201	38.7															201	200	19
53	320	34.6														319	318	317	31
52	344	31.2													343	342	341	339	33
51	458	29.0												457	456	453	451	449	44
50	412	29.0											411	410	408	406	404	402	40
1949	437	28.3										436	435	433	430	428	426	424	42
48	444	27.1									443	442	440	437	435	433	431	426	42
47	346	25.8								345	344	343	341	339	337	336	332	329	32
46	197	25.6							197	196	195	194	193	192	191	189	187	185	18
45	171	27.0						171	170	169	168	168	167	166	164	162	161	159	15
1944	194	28.6					194	193	192	191	190	188	186	184	182	180	177	173	16
43	77	26.6				77	77	76	76	75	75	74	73	72	72	70	69	66	6
42	160	26.8			160	159	158	157	157	155	154	152	150	149	146	142	138	131	12
41	276	26.6		275	275	273	272	270	268	265	262	259	257	251	246	237	226	215	20
40	205	26.3	205	204	203	202	201	199	197	195	193	191	187	182	176	168	160	152	14
No. of models, 1940 and later			205	479	638	711	902	1,066	1,257	1,591	2,024	2,447	2,840	3,272	3,586	3,865	4,022	4,238	4,35
No. before 1940			1,617	1,528	1,435	1,346	1,259	1,177	1,099	1,027	957	887	835	759	694	632	568	508	44
No. at end of each year			1,822	2,007	2,073	2,057	2,161	2,243	2,356	2,618	2,981	3,334	3,675	4,031	4,280	4,497	4,590	4,746	4,80
Census and est. (thous.)			1,582	1,767	1,961	2,065	2,255	2,374	2,500	2,700	2,990	3,250	3,531	3,756	3,946	4,086	4,185	4,310	4,39
Dealers stocks (thous.)			240	240	112	---	---	---	---	---	---	84	144	275	334	411	405	436	40
																Age, life, and horsepower			
Ave. h.p.			25.1	25.4	25.5	25.5	25.8	26.0	26.0	26.0	26.1	26.4	26.8	27.0	27.4	27.9	28.5	29.2	29.
Ave. age (yrs.)			8.4	7.9	7.8	8.3	8.3	8.2	8.2	7.9	7.5	7.3	7.3	7.3	7.5	7.8	8.3	8.6	9.
Ave. useful life (yrs.)			16.8	16.6	17.3	17.2	18.0	17.2	17.9	17.3	17.4	17.0	16.6	16.4	16.2	16.1	16.9	16.5	17.
H.p. on farms (mil.)			40	45	50	53	58	62	65	70	78	86	95	101	108	114	119	126	13

1/ Shipments for farm use 1940-1961, U. S. Bureau of the Census, Current Indus. Rpts. Ser. M35S; 1962-1969, Reports of the Farm and Industrial Equipme
h.p. 1940-1963 estimated from census reports; 1964-1969 estimates are from FIEI data in Implement and Tractor. Intertec Publishing Corp., Kansas City, M
on farms in census years, 1944, 1949, 1954, 1959, and 1964.

(Prepared by Paul E. Strickler, Agricultural Economist, Production Resources Branch, Farm Production Economics Division, Economic Research Service. U.S.

, number of farms, and estimated dealers inventories, 1940-1974 1/

Number remaining at end of--																					
1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
																					120
																				123	122
																			126	125	125
																		130	129	129	128
																	134	133	133	132	132
																144	143	143	142	141	140
															158	157	156	156	155	154	153
														177	176	175	174	173	173	172	170
													185	184	183	182	181	180	179	178	176
												162	161	160	160	159	158	157	156	154	152
											157	156	155	155	154	153	152	151	149	148	146
										155	154	153	153	152	151	150	149	147	146	144	141
									153	152	151	151	150	149	148	147	145	144	142	139	136
								138	137	137	136	135	135	134	132	131	130	128	126	123	120
							124	123	123	122	122	121	120	119	118	117	115	113	110	108	105
						215	214	213	212	211	210	209	206	204	202	200	196	191	187	183	178
					194	193	192	191	190	189	188	186	184	182	180	177	173	169	165	161	157
				186	185	184	183	182	181	180	179	177	175	173	169	166	162	158	154	151	145
			178	177	176	175	174	174	173	171	169	167	166	162	158	155	151	148	144	139	134
		271	270	269	268	267	265	264	261	258	256	253	248	242	237	231	226	220	212	204	196
	201	200	199	198	197	196	195	193	191	189	187	183	179	175	171	167	163	157	151	145	139
319	318	317	315	314	312	310	307	304	301	298	291	285	278	272	266	259	250	240	230	220	207
342	341	339	337	335	334	330	327	323	320	313	306	299	292	286	279	268	258	248	237	223	206
453	451	449	447	444	440	435	431	426	417	408	398	389	380	371	357	344	330	315	297	274	247
406	404	402	400	396	391	387	383	375	367	358	350	342	334	321	309	297	284	267	247	222	197
428	426	424	420	415	411	406	398	389	380	371	363	354	341	328	315	301	283	262	235	209	179
433	431	426	422	417	413	404	395	386	377	369	360	346	333	320	306	289	266	239	213	182	147
336	332	329	325	322	315	308	301	294	287	280	270	260	249	238	224	207	186	166	141	114	86
189	187	185	183	179	175	171	167	164	160	154	148	142	136	128	118	106	95	81	65	49	35
162	161	159	156	152	149	145	142	139	133	128	123	118	111	103	92	82	70	56	43	31	21
180	177	173	167	159	151	144	136	126	114	101	87	74	60	48	39	31	23	17	14	10	8
70	69	66	63	60	57	54	50	45	40	35	29	24	19	15	12	9	7	5	4	3	2
142	138	131	125	118	112	104	94	83	72	61	50	40	32	26	17	14	10	8	6	5	3
237	226	215	204	193	179	163	144	124	105	86	69	55	44	33	25	19	14	10	8	5	3
168	160	152	144	133	121	107	92	78	64	51	41	33	25	18	14	10	8	6	4	2	0
3,865	4,022	4,238	4,355	4,467	4,580	4,698	4,714	4,734	4,758	4,777	4,794	4,814	4,851	4,875	4,870	4,847	4,792	4,718	4,623	4,502	4,356
632	568	508	446	380	320	258	216	170	133	104	76	56	41	30	21	14	9	4	2	0	0
4,497	4,590	4,746	4,801	4,847	4,900	4,966	4,930	4,904	4,891	4,881	4,870	4,870	4,892	4,905	4,891	4,861	4,801	4,722	4,625	4,502	4,356
4,086	4,185	4,310	4,392	4,434	4,481	4,488	4,503	4,520	4,542	4,569	4,599	4,618	4,635	4,645	4,635	4,620	4,601	4,522	4,425	4,302	4,156
411	405	436	409	413	419	478	427	384	349	312	271	252	257	260	256	241	200	200	200	200	200
Age, life, and horsepower																					
27.9	28.5	29.2	29.7	30.3	31.0	31.8	32.4	33.2	34.0	35.0	36.0	37.1	38.4	40.0	41.1	42.4	43.7	45.1	46.7	48.5	50.5
7.8	8.3	8.6	9.1	9.6	10.0	10.3	10.8	11.3	11.7	12.1	12.5	12.9	13.2	13.5	13.9	14.3	14.6	14.9	15.1	15.3	15.4
16.1	16.9	16.5	17.1	17.1	17.5	17.7	18.4	18.8	19.0	19.2	19.8	19.7	19.8	20.2	20.6	20.9	21.3	22.2	22.7	23.4	23.8
114	119	126	130	134	139	143	146	150	154	160	166	171	178	186	190	196	201	204	207	209	210

Farm and Industrial Equipment Institute; 1970-1974, estimated from projected average h.p. and assumed 10 million h.p. annual sales to farmers. Average
ishing Corp., Kansas City, Mo., April 21, 1970. 1970-1974, projection of earlier estimates and dealers' stocks held constant at 200,000 units. Number

omic Research Service, U.S. Department of Agriculture, October 1970)